Nitrate Levels in Wells

Virginia SOL

- *Science* ES.7, ES.9
- *Social studies* WG.1, WG.7, WG.12, GOVT.1
- *Language arts* 9.6, 9.8
- *Technology* C/T12.2, C/T12.3, C/T12.4

Objectives

- Discuss dangers of high nitrate levels in well water
- Perform nitrate testing on well water samples
- Create a map of nitrate levels in well water for the local area
- Compare nitrate levels for older, shallower wells with levels for newer, drilled wells
- Interpret measurements of nitrate levels relative to drinking water standards
- Identify possible sources of nitrates in well water
- Propose collaborative solutions for problems of high nitrate levels
- Produce public information on issues relating to nitrates in well water

Materials

- Nitrate field test kits
  (See Resources at the end of the lesson for vendor information and Appendices at the end of the packet for information on grant funding.)
- Large-scale maps or aerial photographs of local area
  (Information is given in the lesson about obtaining these from USGS.)
- Materials for students to make large-format maps
- Materials for poster displays

Safety & Regulations

Students will need to follow manufacturer safety directions when using nitrate test kits.

Time Needed

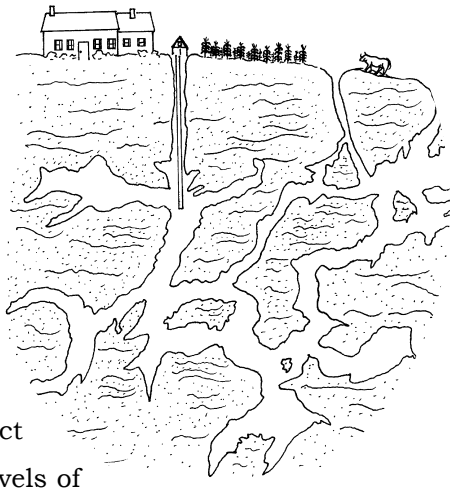
This lesson is written as a long-term project.

Is there any evidence of high levels of nitrate in well water in our local community?

This lesson describes a community project for students to measure nitrate-nitrogen levels in well water. The lesson is designed for students in a ninth-grade Earth Science course.

Nitrate contamination of groundwater is a problem around the world, as well as here in Virginia. The U.S. Environmental Protection Agency (EPA) does not oversee private wells, but it encourages households using wells to test their water annually for nitrate. Water samples can be sent to private laboratories for testing. Typically this will cost between $30 and $50 for each nitrate and coliform bacteria test. A list of certified water testing labs in Virginia can be obtained from the Virginia Water Resources Research Center's web site (*www.vwrrc.vt.edu/advisor/testmain.htm*) or from the State Certification Officer (Laboratory Certification Officer, One North 14th Street, Richmond, VA 23219. Call 804-786-7905.) Also, some local health departments and water treatment plants will test private water for a small fee.

There are legally enforceable standards that apply to public water systems. These National Primary Drinking Water Regulations (NPDWRs or primary standards) can be accessed through the EPA web site (*www.epa.gov/ebpages/watewterpollutionlegalaspects.html*). These primary standards are in place to protect public health by limiting the levels of



contaminants in drinking water. For nitrate the Maximum Contaminant Level (MCL) is set at 10 milligrams per liter (mg/L) of nitrate-nitrogen. The MCL is the highest level of nitrate allowed in drinking water. This level is based on case studies in which fatal poisonings in infants occurred after ingestion of groundwater containing nitrate concentrations greater than 10 mg/L. Unpolluted water normally has less than 1 mg/L (or part per million) of nitrate-nitrogen.

There are serious potential health effects from ingesting water containing high levels of nitrate. Infants below the age of six months who drink water that contains nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue baby syndrome (described later in this lesson). Consumption of excessive nitrates can also cause health problems for pregnant women. Farmers should also be concerned, as excessive nitrates in groundwater can cause health problems in sheep, cattle, and the young of other farm animals, including horses, chickens and pigs.

Nitrates can enter groundwater from human activity and natural causes, and some possible sources are mentioned later in this lesson. Groundwater is part of the water cycle. Just as our land-use decisions can impact the quality of our surface waters, including rivers and the Chesapeake Bay, so too our actions impact the quality of our groundwater. Studies by the U.S. Geological Survey have found that groundwater discharge is a significant source of nitrate load to tidal creeks, coastal estuaries, and the Chesapeake Bay.

Students will need commercial test kits in order to carry out their own nitrate tests on well water samples. Kits can be purchased from the Hach Company or from the LaMotte Company. Contact information for both of these vendors is provided at the end of this lesson, and see the Appendices section of this packet for help seeking grant funding. It is important to remember that measurements of nitrate levels from field test kits are not as accurate as measurements from laboratory procedures. Nevertheless, kit measurements are good indicators.

Much of the information for writing this lesson was taken from web documents provided by the Nebraska Cooperative Extension (web sites listed at the end of the lesson under Resources).

LESSON INTRODUCTION

Discussing dangers of high nitrate levels in well water...

To begin this lesson, tell students about dangers of high nitrate levels in well water. You may assign students to use the Internet to carry out their own background research on dangers of high nitrate levels. After students have had time to search for information, they can work in small groups to summarize the information, and then share their work with other groups.

Nitrogen is essential for living things as an essential component of proteins. Nitrogen exists in many forms and changes between these forms as it moves through the nitrogen cycle. Nitrate is one of the water-soluble forms of nitrogen. When excessive concentrations of nitrate-nitrogen are found in drinking water, this can be hazardous to health, especially for infants and pregnant women.

Nitrate itself is a relatively non-toxic substance. However, nitrate (NO_3^-) can be converted into nitrite (NO_2^-) by bacteria, and this can occur in the environment, in foods, and in the human body. Methemoglobinemia is a blood disorder caused by nitrite interacting with hemoglobin in red blood cells. Hemoglobin is converted to methemoglobin, and this results in insufficient amounts of oxygen being transported to the body's cells and tissues. Methemoglobinemia is rare among adults but is more likely to occur in young infants. Infants younger than about six months secrete less gastric acid and have a less acidic digestive system than healthy adults. This results in more bacteria and greater amounts of nitrate converted to nitrite. Infants also have a low concentration (about 60% of the adult concentration) of an enzyme responsible for converting harmful methemoglobin back to hemoglobin. Infants suffering from methemoglobinemia may show intermittent signs of blueness around the mouth, hands, and feet, hence the common name for the condition of “blue baby” syndrome. The baby may also display trouble breathing, diarrhea, and vomiting. In more severe cases, the baby will show marked lethargy, excessive salivation, and loss of consciousness. Death can occur in extreme cases.

Cases of methemoglobinemia can usually be treated effectively by simply changing to drinking water containing less than 10 mg/L of nitrate-nitrogen. (Severe cases are treated with intravenous administration of a solution of methylene blue.) Methemoglobinemia prevention is important for infants. It is also important for pregnant women, women who are breast feeding, and certain other high-risk individuals. Some adults have a diminished capability to secrete gastric acid leading to increased conversion of nitrate to nitrite. Some older individuals are at risk from a deficiency of the enzyme for converting methemoglobin to hemoglobin. It is especially important for all individuals at risk for methemoglobinemia to use water with nitrate-nitrogen below the EPA MCL standard of 10 mg/L.

Planning for a community project testing well water...

The project can begin by having students in the class with wells at home volunteer for having samples of their water tested. The project can also be advertised in the school, and students in other classes may also volunteer to have their well water tested. Finally, you may choose to enlarge the project by advertising for well samples from members of the community at large. Well water samples

should only be tested if they are received along with a permission slip completed by the homeowner family. A sample letter and permission slip are provided with this lesson as separate pages.

Students will carry out nitrate testing on samples that are volunteered. They will eventually compile the data measurements together and make final conclusions concerning nitrate levels in groundwater in your community. The students will also respond to individual homeowners who submitted well water samples. Students will report the result of testing, an interpretation of the test result, and any follow-up actions to be recommended for the homeowner. It is suggested that the class be divided up into small groups, with each group to be responsible for those homes submitting samples from an assigned geographical section of the local community.

ACTIVITY PROCEDURES

Performing nitrate testing on well water samples...

To carry out the nitrate tests, students need nitrate test kits. These simple to use kits can be obtained from the Hach Company or the LaMotte Company. Contact information for both vendors is listed in the Equipment and Technology appendix. See the Appendices section of this packet for information about applying for grant support to fund these kits. Students will perform tests on well water samples as they are received and enter results into a class data notebook to be a permanent record of all samples tested. A system should also be set up for homeowners to be notified as quickly as possible of the test result for their sample. It is suggested that this be done by telephone, whenever possible by the students themselves. If a sample shows a

Which Nitrate Test Kit to Use?

The results of nitrate tests can be expressed as either nitrate-nitrogen (NO_3-N) or as nitrate (NO_3^-). Since the Virginia standard for drinking water quality is for NO_3-N, we recommend that you use a test kit that will measure nitrate-nitrogen. Test kits also come in a variety of measurement ranges. We recommend that the high-end of the range be 10.0 to 15.0 mg/L. This means that a test kit with a range of 1.0 to 15.0 mg/L is preferable over a kit with a range of 0.25 to 1.00 mg/L.

Most nitrate-nitrogen test kits are colorimetric. This means that, when you mix a water sample with the chemicals (reagents) that come with the kit, a color will develop in a test tube in the presence of nitrate. Darker colors correspond to higher concentrations. Students will compare the color in the water sample to standards that come in the kit. If one of the water samples develops a very dark color – darker than the darkest standard – you may need to dilute the water sample with water that is known to be free of nitrates. Then, be sure to multiply the results by the dilution factor.

Also, note that some kits express results in parts per million (ppm) instead of milligrams per liter. These units are equivalent, so 1 ppm = 1mg/L

nitrate-nitrogen level of 7 mg/L or greater, the homeowner should be instructed to confirm the result with a certified lab test.

Creating a map of nitrate levels in the local area...

The class should work together to create a display map of nitrate levels for wells throughout the local area. Students can either label an existing map or they can make their own large-format map based on an existing map. You may also choose for students to work from an aerial photograph of the area.

Detailed large-scale maps of the area may be available locally. Topographic maps can also be ordered from the United States Geological Survey (USGS) through their web site (*http://edc.usgs.gov*). The appropriate maps can be identified on the web site through the site Online Map Lists and ordered for $4–7 each (estimated cost). Aerial photographs from the USGS National Aerial Photography Program (NAPP) can be easily located at the USGS web site using the site PhotoFinder feature. Photographs are available taken in 1989, 1994, and 2000 and can be ordered for $10 if black and white or $16 if colored (estimated costs). Students can also look at topographic maps and aerial photographs on the Internet free of charge. This can be done through the USGS site http://mapping.usgs.gov. This site has links to several sources for viewing maps and photographs. Terraserver is one site where both maps and photographs can be viewed (*http://terraserver.homeadvisor.msn.com*). USGS topographic maps of any part of the country may also be found conveniently at the Topozone web site (*www.topozone.com*).

Students will need to be able to read their local map to locate the sites of the wells that were tested. If Global Positioning System (GPS) units are available, students can determine longitudes and latitudes for well sites, and use the longitude and latitudes to find well locations on a topographic map. To preserve the privacy of participating families, only approximate locations should be marked on maps. Specific addresses should not be identified. Students should work together as a class to create a large display map with the approximate locations marked of wells that they have tested. Small groups of students can continue to be responsible for their own sections of the whole area studied.

When creating their map of nitrate levels, the students could color code the locations according to the different measured nitrate levels. Also, for proper interpretation of data, students will need to distinguish older, shallower wells that were dug or bored from newer and deeper drilled wells. Students can try to determine whether older, shallower wells have higher incidences of nitrate contamination. According to studies conducted by the Virginia Cooperative Extension's Rural Household Water Quality Education Program, bacterial contamination is the most widespread problem in the wells they tested, and older, shallower wells show higher incidences of bacterial contamination. (See The Importance of Groundwater earlier in this section.)

Interpreting measurements relative to EPA drinking water standards...

Students should interpret the nitrate measurement data they have collected relative to the EPA MCL standard for nitrate-nitrogen of 10 mg/L. Measurement data can be transferred to either spreadsheet or database software for easy sorting in order to determine trends and patterns in the data. Each student can be asked to prepare a summary of the class data, including data values and a written conclusion of how the data compare to the EPA standard. An individual written summary can be an assessment of each individual student's understanding, but students should first have opportunities to discuss their conclusions with other students, both in small groups and as a whole class.

Possible sources of nitrates in well water...

Have students identify and discuss possible sources of nitrate in well water. Students can carry out research on this and work in small groups to summarize their work.

Nitrate-nitrogen can enter groundwater due to both natural events and human activity. Nitrate readily leaches out of the soil by rainfall. The rate of leaching depends on many factors, including the amount of fertilizer applied, geology, topography, rainfall pattern, crop utilization of fertilizers, and soil type. A major source of nitrates in well water is run-off from fertilizer use on cropland, parks, golf courses, or lawns and gardens. Other important sources include leaching from septic systems, animal manure, land application of municipal or industrial sludge, and natural sources, such as the release of nitrate when bacteria in the soil break down organic matter.

The area immediately around a wellhead can be a source of contamination. People with wells can protect their drinking water quality by managing the land surface around their well. This is called wellhead protection. The wellhead is the upper portion of the well including the well cap. A poor fitting well cap or a break in the seal causes most contamination problems. Homeowners should not store chemicals, gasoline, oil, etc. near the wellhead or in the pump house. Likewise, steps should be taken to keep other contaminants, like fertilizer and animal waste, away from the wellhead.

Another factor that influences the amount of contaminant reaching groundwater has to do with the recharge rate (or infiltration rate). As discussed in The Importance of Groundwater chapter, the recharge rate differs depending on where in Virginia you live.

Solutions for high nitrate levels...

Have students work in small groups to research solutions for problems of high nitrate levels. There are two basic approaches to reducing the nitrate concentration in groundwater. First, steps can be taken to prevent nitrates from entering groundwater. Preventative steps include wellhead protection, septic tank maintenance, and improved nutrient applications on agricultural fields, golf courses, and lawns. Also, chemicals, motor oil, and other contaminants should never be poured

on the ground, and the area around sinkholes should be kept free of trash and all possible pollutants. Many preventative practices, often called “Best Management Practices” can be found on the Internet for homeowners and farmers. It must be remembered that changes in nitrate concentrations may take a long time to be detected in groundwater, as the recharge rate (rate at which water percolates through the soil to reach the water table) can be slow. Since water can remain in an aquifer for several decades or thousands of years, the quality of groundwater reflects the effects of land use when the water was recharged, as well as processes that alter the water's chemistry as it flows through the aquifer. Changes in groundwater quality might lag changes in land use and agricultural practices by years or decades, so it is important to adopt Best Management Practices now to protect water quality in the future.

The second approach is to reduce the concentration of nitrates in the water by using some type of special treatment to remove nitrate from the water. Nitrate can be removed from water by three different treatments: distillation, reverse osmosis, or ion exchange. Home treatment equipment using each of these processes is available from various manufacturers. All of the three treatment methods can be relatively expensive, both in initial cost and ongoing operating and maintenance costs. The Water Quality Association (WQA) and the National Sanitation Foundation (NSF) both test water treatment equipment for manufacturers, and equipment that has been tested satisfactorily should be labeled accordingly. Some people purchase under-the-sink treatment units, and treat only the water they drink and cook with, leaving the rest of their household water untreated. Note that carbon adsorption filters, mechanical filters of various types, and standard water softeners do not remove nitrate from water. Nor does boiling of water. In fact, as with other inorganic chemical pollutants, boiling water will increase the nitrate concentration due to evaporation.

Sometimes the least expensive (and quickest) approach is using an alternative water supply, such as bottled water, for drinking and cooking needs. This alternative might be considered if the primary concern is water for infant food and drinking. Obtaining a permanent new water supply will likely require drilling a new well, either a well in a different location or a deeper well at the same location. If the original well is drawing water from a shallow aquifer, there may be a deeper aquifer protected by a clay layer stopping downward movement of nitrate-contaminated water.

Communicating consequences of high nitrate levels...

Work with students to help them make an effective display of the results of their work. Encourage the students to use word processing and computer graphics programs as appropriate. Students might create a poster display for their school building. Where possible, students might publish the results of their work on a school web site. Students can work as a class to create a leaflet summarizing their

results for distribution to homeowners and others in the community.

Students should be able to describe the trends of relative nitrate levels in wells throughout their community. They should also be able to communicate to their public audience why nitrates in drinking water are a problem, where nitrate contamination comes from, and what steps can be taken if water is high in nitrates.

Sharing recommendations for controlling nitrate levels...

As stated in the Oregon Groundwater Community Involvement Program (Testing Oregon Wells for Nitrates. (1994). The Volunteer Monitor, 6(2), 13.), the idea is not to point fingers at specific community members and label them as the problem. Rather, a program of this kind can "demonstrate how groundwater pollution can come from many sources, and since we're all part of the problem we all need to work together to clean up and prevent groundwater contamination."

QUESTIONS

- How many different well samples were tested for nitrate level?
- What procedure did you use to test the nitrate level of the water samples?
- How many of the well samples tested at 10-mg/L nitrate-nitrogen or higher?
- What trends or patterns are there in the locations of wells that tested for high levels of nitrate?
- How do nitrate levels compare for older, shallower wells that were dug or bored and newer, drilled wells?
- How would you summarize the evidence for or against a high nitrate levels problem in wells in our local community?
- How do our land use decisions impact the quality of groundwater?
- What kinds of actions could be taken around wellheads to reduce surface water entering the well?
- What would you recommend to reduce the problem of high nitrate levels?

ASSESSMENTS

- Quality of Internet research on either dangers of high nitrate levels, possible sources of nitrates in well water, or possible solutions for high nitrate levels.
- Performance while carrying out nitrate testing on well water samples.
- Working in small groups and cooperating with other groups as a whole class.
- Individual written summaries of data measurements and conclusions.
- Working with class on presentation of final conclusions and recommendations.

EXTENSIONS

- Students can continue to track nitrate levels over an extended time on an ongoing basis. Testing in selected wells four times a year allows monitoring of seasonal changes in nitrate concentrations.
- Students could examine the wellhead area around several wells to see if actions could be taken to reduce surface water from entering the well.
- Students can communicate and correspond with other organizations involved in groundwater studies, for example local Soil & Water Conservation District, the Virginia Department of Environmental Quality, or the Virginia Groundwater Protection Steering Committee.
- Students in Karst areas could learn about sinkholes in their county. They could learn from county officials what steps are taken to protect groundwater quality or to educate the public.
- Students can explore participation in other community involvement programs.

RESOURCES

For the teacher...

- A Grave Mistake. *Project WET*.
- American Ground Water Trust. *www.privawater.com*
- National Mapping Information. USGS. *http://mapping.usgs.gov*
- *NebGuide "Drinking Water: Nitrate-Nitrogen."* (1998). Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln. *www.ianr.unl.edu/pubs/water/g1279.htm*
- *NebGuide "Drinking Water: Nitrate and Methemoglobinemia ('Blue Baby' Syndrome)."* (1998). Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln. *www.ianr.unl.edu/pubs/water/g1369.htm*
- Nitrates in Groundwater. Canter, L. W. (1997). Boca Raton, FL: CRC Press, Inc.
- Terraserver. *http://terraserver.homeadvisor.msn.com*
- Testing Oregon Wells for Nitrates. (1994). The Volunteer Monitor, 6(2), 13.
- The Pucker Effect. Project WET.
- Topozone. *www.topozone.com*
  USGS maps for the entire United States can be viewed online.
- United States Geological Survey. *http://edc/usgs.gov*
- Virginia Groundwater Protection Steering Committee. *www.deq.state.va.us/gwpsc*
- Virginia Water Resource Research Center. *www.vwrrc.vt.edu*

Nitrate Levels in Wells – Permission Letter

Dear Homeowner,

Ninth-grade Earth Science students at _____ School are currently working on a community project to provide nitrate testing of well water samples for homeowners in our local area. You are invited to participate in this project by providing a sample of your well water for the students to test. There will be no cost to have your sample tested.

In order to have a sample of your well water tested by our students, you should provide a water sample of about one or two cups volume in a clean sealed jar, labeled with your name, address, and phone number. The students will test the water sample and then notify you of the test result. You will also receive a short interpretation of the test result, and any possible follow-up actions that might be recommended. Students will also be preparing a final summary of their project, evaluating nitrate levels measured in wells throughout the community, and you will receive a copy of that information. The students' summary will not include specific addresses in order to keep this information confidential.

It is important to know the level of nitrate in well water. The U.S. Environmental Protection Agency's Maximum Contaminant Level (MCL) for nitrate in drinking water is 10 milligrams per liter (mg/L). Higher levels are a health risk for infants and pregnant women because they can cause "blue baby" syndrome (methemoglobinemia), a condition that interferes with the oxygen-carrying capacity of the blood. Certain adult individuals can also be at risk for methemoglobinemia. It should be noted that the testing program being carried out by the students at school is an indicator of nitrate level in your well water, but not as accurate as a test carried out by a certified lab. If we find a high nitrate level in your water, we will recommend that you then have a test carried out by a certified lab.

If you would like to participate in this project, please fill out and sign the attached sheet, and return the permission slip to school along with your water sample for testing.

Sincerely,

Mr./Ms. Teacher

_____ School

__ / __ / __

Nitrate Levels in Wells – Permission Slip

I would like to voluntarily submit a sample of my private well water for testing by the Earth Science students at _____ School. I understand that the results of my test will be given to me, but will not be made public.

Name: _____

Address: _____

_____

Phone: _____

Signature: _____

Information about your well

Please fill out as much as possible. Any information you can give us will help our class draw proper conclusions about our tests.

My well is (please check one):

___ Drilled ___ Bored ___ Dug ___ I don't know

My well's depth is: _____ feet.
Check here if you don't know how deep your well is: _____

To the best of your knowledge, when was your well constructed? _____

If you have a septic system, approximately what is the distance between your well and your septic drain field? _____
(Check here if you don't have this information: _____)

If you have a septic system, approximately how long ago was your septic tank pumped?
(Check here if you don't have this information: _____)

Thank you! Please return this to:

NOTES