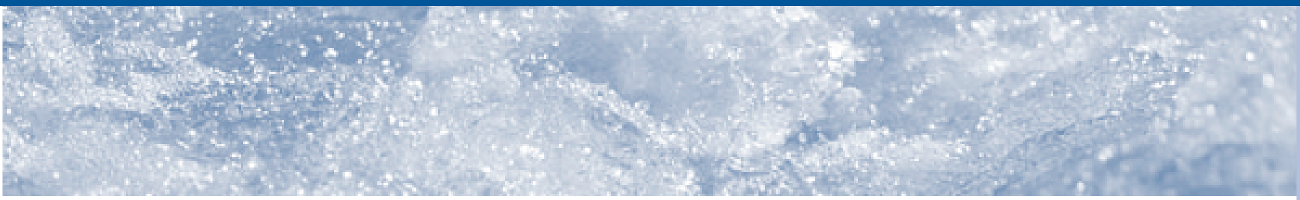
Nitrogen Cycle



Duration:
Classroom
50 minutes

Setting:
Classroom

Link to the Utah Core Curriculum:
Earth Systems – 9th grade
Standard V-1b

ILO's:
1 a-e, h
2 b
3 a, c
4 a-e (if students report data)

Purpose: To diagram the nitrogen cycle and provide examples of human actions that affect this cycle.

Summary: Students will learn about the nitrogen cycle through discussion and the construction of a diagram. They will also measure the nitrate levels in various water samples and discuss how humans affect nitrate content in the water.

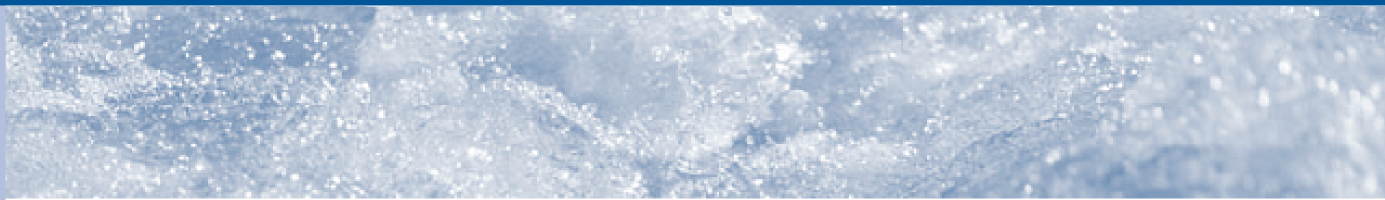
Background: Nitrogen is all around us and is found in a variety of forms throughout the global environment. The nitrogen cycle demonstrates the many different paths nitrogen may follow around our earth and the different reservoirs in which nitrogen is stored.

Although nitrogen gas (N_2) is an important component of proteins for both plants and animals, most plants cannot use the nitrogen gas directly. The process of converting nitrogen to a "biologically available" form – in other words, converting nitrogen gas to a form that plants can use - is called nitrogen fixation. Only specialized bacteria in soil and certain types of algae in water can fix nitrogen. Lightning strikes also result in some nitrogen fixation.

Human activities have had a huge impact on global nitrogen cycles. The amount of biologically available nitrogen generated by human activities now far exceeds nitrogen fixed by bacteria, algae and lightning. Humans produce synthetic fertilizers, burn fossil fuels, grow legumes (which fix nitrogen) as a crop, and engage in various land clearing, burning and wetland draining activities, which all release nitrogen in forms that plants use. See the table on the Teacher Resource page for more details on the amount of fixed nitrogen humans produce.

See the Utah Stream Team Manual or the Further Discussion questions to learn more about the nitrogen cycle and how humans have affected it.

Nitrogen Cycle



Materials:

- Nitrate kits*
- Copies of nitrate sampling instruction sheets
- Waste bottles
- Clip boards
- Pencils
- Plastic water bottles for collecting samples

* For information on equipment for loan or for purchase, contact USU Water Quality Extension at (435) 797-2580 or www.extension.usu.edu/waterquality

Classroom Activity:

Part One

1. Discuss the nitrogen cycle with your students

   - Ask them to identify where nitrogen is found. Talk about how nitrogen is found in many different forms, both organic and inorganic.
   - Ask the students what the most common inorganic form is *(nitrogen gas, which makes up 80% of the atmosphere)*.
   - Ask students where organic nitrogen might be found *(plants and animals and dead material – nitrogen is used in proteins)*.
   - Ask the students what type of nitrogen most plants can use *(nitrate or ammonia – two common forms of inorganic nitrogen)*. Point out that only a few very specialized plants and microorganisms can use nitrogen gas directly. All other plants use nitrogen in the form of nitrate or ammonia.

2. As the students talk about forms of nitrogen. Draw a nitrogen cycle on the board, adding reservoirs and process lines as the students suggest them (see example on the Teacher Resource page).

Part Two

1. Explain to the students that they will measure one type of nitrogen found in water - nitrate. Nitrate is a common form of inorganic nitrogen that is easily used by plants.

2. Provide water samples from different sources. Groundwater, surface water, or water from a fish tank are all good sources.

3. Divide students into groups of no more than six so that everyone can be involved.

4. Give each group a water sample. Have the groups follow the directions found on the nitrate sampling sheet.

5. Have students record their results on the board and discuss why different sources of water have different concentrations.

6. Explain that nitrate is extremely soluble and moves into our groundwater easily. Explain that in surface waters, the nitrate is used up rapidly by aquatic plants.

Part Three

1. Return to the drawing of the nitrogen cycle from your earlier discussion, or use the cycle in this lesson as a guide. Ask the students to suggest ways that humans may have affected the nitrogen cycle.

2. Discuss their answers. Be sure to mention the points below.
   - Inorganic Fertilizers - fertilizers have been produced commercially since the 1950's and now account for 80 tg of fixed nitrogen entering the global environment every year.
   - Feedlots introduce a lot of ammonia into the air.
   - Fossil fuel combustion (cars and coal burning energy plants) convert nitrogen gas into nitric and nitrous oxides, which are dissolved into rainwater and fall as nitric acid. This is not only a source of acid rain, but also nitorgen fertilizer.

Note: 1 tg (terragram) is equal to 1 million metric tons

Nitrogen Cycle

Further Discussion:

1. Discuss the following terms with your students. Be sure they understand how these relate to the nitrogen cycle.

- ***Microorganisms*** *are extremely important in converting nitrogen from one form to another.*
- ***Nitrification*** *is the transformation of ammonia to nitrite and finally to nitrate. This usually happens by microorganisms in conditions with plenty of oxygen.*
- ***Denitrification*** *by a different group of microorganisms is the transformation of nitrate to nitrite and finally to nitrogen gas.*
- ***Nitrogen fixation*** *is the conversion of nitrogen gas to nitrate or ammonia, and occurs when there's little or no free oxygen in the environment (e.g., in the sediments at the bottom of a lake).*

2. What form of nitrogen is measured in the water test?

This test measures the nitrate (NO_3) *+ nitrite* (NO_2) *concentration in the water, but we generally refer to the results as nitrate only, because nitrite concentrations are usually extremely low in surface waters. Nitrate is one of the two common forms of inorganic nitrogen found in water, and is readily used by plants. The other form, ammonia, is less common in unpolluted surface water.*

The nitrate test has two steps. The first step is to shake the water sample with a small amount of ground cadmium. This "strips away" one oxygen atom from the nitrate molecule, converting everything to nitrite. The second step is a color test designed to analyze for nitrite concentrations. The intensity of the pink color is proportional to the amount of nitrite.

3. What are the impacts of the large amounts of biologically available nitrogen released by human activities?

Nitrogen in such abundance has many impacts.

• Over-fertilization of lakes and estuaries is called eutrophication. Runoff of synthetic fertilizers, runoff from feed lots, runoff from drained wetlands, burned areas, and atmospheric deposition all contribute to this problem. The nitrogen stimulates excessive plant growth. The plants eventually die and decompose, which can use up all the dissolved oxygen in the water. This kills fish in lakes, and has also produced an area the size of Massachusetts on the floor of the Gulf of Mexico that is a "dead zone"... no oxygen left so nothing else can live there.

• Burning of fossil fuels creates nitric and nitrous oxide as a byproduct in the atmosphere. This falls to earth as nitric acid, a strong acid that can cause acidification of lakes, especially in areas where soils are not well buffered. Heavy nitrogen deposition on soils can acidify the soils, which damages terrestrial ecosystems. They are also a source of fertilizer.

• Combustion engines also convert nitrogen gas to nitrous oxide, which is a greenhouse gas (traps heat and contributes to global warming).

• Nitrogen can be directly toxic to humans and animals as well. Drinking water nitrate concentrations above 10 ppm (mg/l) cause blue baby syndrome and ammonia at much lower concentrations can be toxic to fish.

Notes

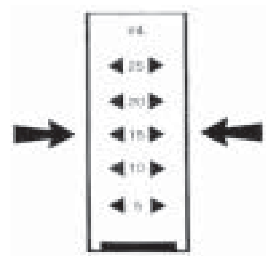
Nitrate

• This test detects nitrate at concentrations of 0.1 to 5 mg/l (ppm).
• The range for this test is 0 to 5 mg/l (ppm).

Time – 15 minutes
Persons - 1
Materials -
  • Chemetrics Nitrate Sampling Kits
Sunlight can damage the ampoules in your Nitrogen kit. Keep them shaded at all times.

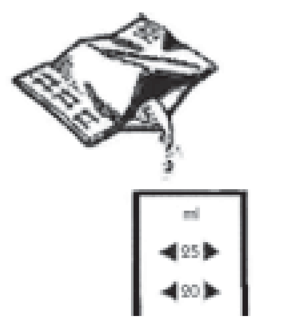
Step 1

1. Pre-rinse collection bottle with stream water.
2. Fill the sample cup to the 15 ml mark with your water sample.



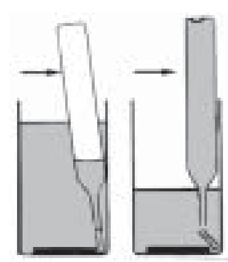
Step 2

1. Empty the contents of one Cadmium Foil Packet into the sample cup. Use caution when handling the Cadmium Packet. Tear it carefully or open with scissors. Do NOT use your teeth.
2. Cap the sample cup and shake it vigorously for exactly 3 minutes.
3. Allow the sample to sit undisturbed for 30 seconds.



Step 3

1. Place the ampoule in the sample cup.
2. Snap the tip by pressing the ampoule against the side of the cup. The ampoule will fill leaving a small bubble to help mixing.



Step 4

1. Mix the contents of the ampoule by turning it up and down several times, allowing the bubble to travel from end to end each time.
2. Wipe all liquid from the outside of the ampoule.

Nitrate - Continued

Step 5

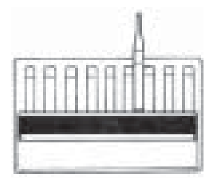
1. Wait 10 minutes for color development.

Step 6

1. Use the appropriate comparator to determine the level of nitrate-nitrogen in the sample. For low range, use the tube comparator. For high range use the rack comparator.

a. Tube Comparator – Place the ampoule, flat end down into the center tube of the low range comparator. Direct the top comparator toward the sun or another bright light source while viewing from the bottom. Rotate the comparator until the color standard below the ampoule shows the closest match.

b. Rack Comparator – Hold the rack horizontal while standing underneath a bright light source. Place the ampoule between the color standards moving it from right to left along the comparator rack until the best color match is found.



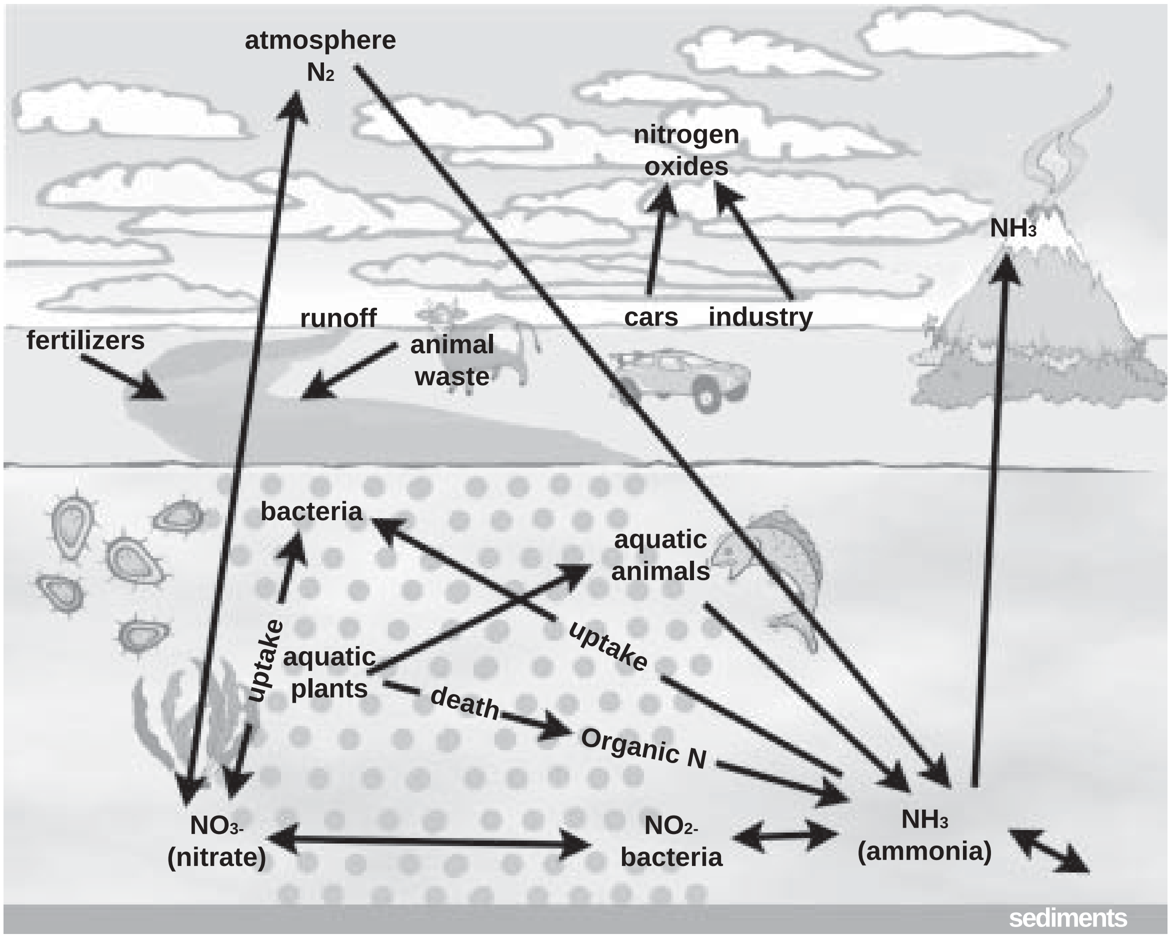
Step 7

1. Record the number of the best match on the comparator on the board. This is your nitrate-nitrogen concentration in mg/l (ppm).

In Utah:
The maximum concentration of nitrate allowed in drinking water is 10 mg/l.

The State of Utah considers nitrate concentrations of 4 mg/l in stream water to be an indicator of pollution problems.

The Nitrogen Cycle



Source: Gilbert Graphics

Global reservoirs of nitrogen:
Stream and lake sediment
Living plants
Living animals
Dead plants and animals
Animal waste
Soils
Atmosphere
Lakes and rivers
Ocean
Fertilizers
Groundwater
Rain water

How nitrogen moves from one reservoir to another:
Uptake by plants
Eaten by animals
Decay of dead material
Rainfall
Surface runoff
Bacterial conversion
Nitrogen fixation
“Denitrification”
“Nitrification”
Lightning
Volcanic eruptions
Animal waste
Groundwater movement

Nitrogen Sources

Global Sources of Biologically Available (Fixed) Nitrogen	
ANTHROPOGENIC (HUMAN) SOURCES	**ANNUAL RELEASE OF FIXED NITROGEN (teragrams)***
Fertilizer	80 tg
Legumes and other plants grown as crops	40 tg
Fossil fuels (coal plants and automobliles)	20 tg
Biomass burning	40 tg
Wetland draining	10 tg
Land clearing	20 tg
Total from human sources	**210 tg**
NATURAL SOURCES	
Soil bacteria, algae, lightning, etc.	140 tg

Source: Peter M. Vitousek at al. 1997. "Human Alteration of the Global Nitrogen Cycle: Causes and Consequences, " Issues in Ecology, No. 1, pp. 4-6.

* 1 tg (terragram) is equal to 1 million metric tons

Notes