EnviroTEACH

An environmental education resource for teachers

Term 1 – 2019

From the editor

Kia ora! The aim of this publication is to try to explain in clear and simple language why nitrogen is relevant in the lives of Southlanders and why nitrogen management is such an essential part of looking after our environment. It's a complex topic that can seem a bit obscure - so this publication offers some suggestions for ways to make the topic more relatable and engaging for students.

It includes information for teachers, experiments and activities you can do in the classroom, and actions that everyone can take to help protect water from nitrogen contamination.

You are welcome to contact Environment Southland for more information on this topic, or for assistance with teaching and learning about this or any other environment-related topic.

Pat Hoffmann

Environmental education officer, Environment Southland

Environmental technical officer Bee Pikia collects a water sample to send for testing.

environment SOUTHLAND REGIONAL COUNCIL
Te Taiao Tonga

What is nitrogen and why is it important?

Nitrogen is a chemical element that is essential for growth and survival of all life on earth. It is part of DNA, RNA and proteins - the building blocks of life – and is found in all living things from the tallest trees to the tiniest microorganisms. Nitrogen is also one of the most important fertilisers for plant growth. But when nitrogen gets into rivers, it can lead to excessive growth of algae, cause river habitats to deteriorate and may even poison fish. Excessive levels of nitrogen in drinking water are harmful to human health.

Nitrogen is often referred to using the chemical symbol N. It is an incredibly versatile element as it has the ability to change its form through chemical reactions, and move through the atmosphere, soil, water and living organisms.

The gaseous form of nitrogen (N_2) is very abundant in our atmosphere. The air we inhale is made up of about 78% nitrogen, 20% oxygen and small amounts of other gases. However, most plants and animals don't have the ability to use nitrogen directly from the atmosphere. Plants get their nitrogen from the soil and animals get their nitrogen from the food they eat.

Plants need nitrogen for growth, metabolism, and photosynthesis. Nitrogen is a component of chlorophyll which is the pigment that gives plants their green colour and allows them to capture energy from the sun. Plants take up nitrogen from the soil through their roots, but they can only use nitrogen that is in the form of either ammonium (NH_4^+) or nitrate (NO_3^-) or urea ($(NH_2)2CO$). If a plant is deficient in nitrogen it can't make enough chlorophyll, its leaves turn yellow and its growth becomes stunted.

Animals obtain nitrogen by eating food that contains nitrogen (i.e. plants or other animals). Nitrogen is an important part of the human body too, because our bodies need it to build DNA and the proteins that make up our hair, muscles, skin and other tissues. People who don't get enough nitrogen in their diet may suffer from hair loss, muscle weakness and their wounds may take longer to heal.

ACTIVITY

Identify an area that has white clover plants growing in it. Select a healthy-looking plant and dig it out, getting as much of the root material out as you can. You will need to dig a hole at least as deep and as wide as the blade of your spade.

Remove the plant and place it on a plastic sheet. Gently remove the soil from around the roots with your hands, or pour a bucket of water over the roots to loosen the soil. Look for root nodules (small swellings on the roots).

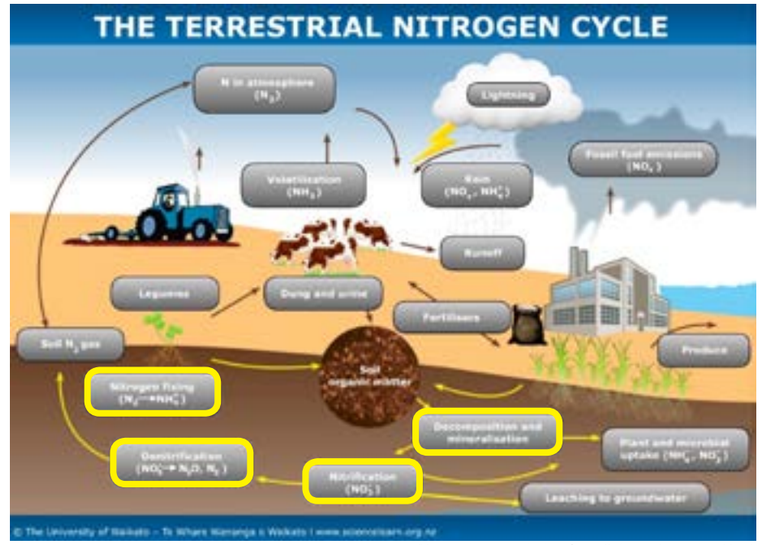
Use a sharp knife to cut open a few root nodules and examine them with a magnifying glass. If the nitrogen-fixing bacteria are active, the nodules should be pink or red inside. Nodules that are green or white are young and inactive, while nodules that are grey or brown are old.

Extend the investigation by comparing clover plants from paddocks that have been fertilised with plants from areas (such as roadsides) that have not been fertilised. Remember to get permission from the landowner first! Do you notice any differences? Repeat the activity with other legume species such as beans, peas, lupins or red clover.

Leguminous plants such as clover have nitrogen-fixing bacteria living inside their root nodules. These bacteria are able to convert nitrogen gas (from the atmosphere) into ammonium, which the clover plant can use to grow.

The nitrogen cycle

The movement of nitrogen between the soil, atmosphere, water and living things is called the nitrogen cycle.



(Used with permission from Science Learning Hub)

- **Nitrogen fixation** is the process in which atmospheric nitrogen (N_2) is converted to ammonium (NH_4^+). Ammonium is important, because plants are able to take up and use nitrogen when it's in this form. Nitrogen-fixing bacteria (e.g. *Rhizobium*) have the ability to fix atmospheric nitrogen. Many have symbiotic relationships with host plants (legumes such as beans, peas and clover). They live inside the root nodules of their host plant and receive carbohydrates in exchange for ammonium.
- **Decomposition and mineralisation:** When plants and animals die, decomposers (e.g. bacteria and fungi) consume the organic matter and decomposition occurs. The nitrogen contained within the organic material is converted back to ammonium and becomes available for uptake by other plants and soil microorganisms. This is one of the reasons why compost is so good for your vegetable garden.
- **Nitrification** is the process in which soil microorganisms convert ammonium to nitrate (NO_3^-). Like ammonium, nitrate is a plant-available form of nitrogen, which means that plants are able to take it up and use it. Nitrification can only happen if oxygen is present in the soil (e.g. in well-drained and aerated soils). One important difference between nitrate and ammonium is that nitrate is highly soluble. That means that it dissolves in water and so, in well-drained soils, nitrate can leach out of the soil very easily. In contrast, ammonium attaches itself to soil particles and resists being leached out of the soil.
- **Denitrification** is the process in which nitrate is converted to back to gaseous forms of N. This occurs in the absence of oxygen (e.g. when the soil is saturated).

ACTIVITY

Observe the nitrogen cycle in action

The Science Learning Hub has instructions for an excellent experiment which helps students to explore and understand two processes in the nitrogen cycle: nitrification and denitrification.

Students use a nitrate test kit to test a solution, daily, for the presence of nitrate. Then, over a period of 2-3 weeks, they observe (through measurement) how ammonium gets converted to nitrate (nitrification) in the presence of oxygen and how nitrate gets converted to nitrogen gases (denitrification) in the absence of oxygen.

www.sciencelearn.org.nz/resources/978-nitrification-and-denitrification

Sources of nitrogen for growing plants

Commercial fertilisers

If your plants are deficient in nitrogen, you can give them a boost by feeding the soil with nitrogen fertiliser. Fertiliser helps to keep nutrients at the most suitable level for plant growth and development. Many commercial nitrogen fertilisers contain a combination of ammonium, nitrate and urea.

Compost

In nature, plants get nitrogen from decomposing organic material in the soil. Decomposition is nature's way of recycling. You can take advantage of the decomposition process by making your own compost. Compost is very beneficial because it enriches the soil and helps it to retain moisture. It also reduces the need for commercial fertilisers.

Organic nitrogen

There are several organic methods of providing nitrogen for growing plants including: adding composted manure to the soil, planting a green manure crop such as borage, planting nitrogen-fixing plants such as peas or beans in rotation with other crops, and adding coffee grounds to the soil.

Make your own compost

Lots of schools in Southland have vegetables gardens and orchards, and many make their own compost to feed their growing plants. You can make your own compost by collecting food scraps and garden waste at school and adding them to traditional compost heaps, worm farms or bokashi bins.

▲ A food scrap bucket at St Teresa's School in Bluff

▲ Worm farms at Gore Main School

▲ Bokashi bin

ACTIVITY

Set up an experiment to compare the development of plants grown with nitrogen fertiliser to plants grown without nitrogen fertiliser. Monitor plant growth for 2-4 weeks and get students to record their observations e.g. height, number of leaves on each plant, colour and any other things they notice.

You can extend the experiment by comparing different amounts of nitrogen fertiliser to see what the ideal concentration is for growing plants, or by testing different types of fertiliser.

Design your own experiment or follow the step-by-step instructions here: www.sciencebuddies.org/science-fair-projects/project-ideas/PlantBio_p012/plant-biology/nitrogen-fertilizers-plant-growth

If nitrogen is so important, what's all the fuss about?

Small amounts of nitrogen are a natural component of healthy rivers. But when too much nitrogen gets into waterways it causes aquatic weeds and algae to grow too fast and can lead to algal blooms. This increased plant growth reduces oxygen levels in the water and can threaten aquatic ecosystems. High levels of nitrogen are toxic to aquatic life and can cause fish to die.

Excessive levels of nitrate in drinking water have been linked with a blood disease in babies called 'blue baby syndrome'.

What is a safe nitrate level in drinking water?

The Drinking Water Standards for New Zealand set a maximum acceptable level of 50mg/L for nitrate, which is equivalent to 11.3mg/L of nitrate-nitrogen. Some laboratories report how much nitrate is in the sample while others report how much nitrate-nitrogen is in the sample. If you are getting your water tested, make sure you know what they are reporting.

ACTIVITIES

Get your students to do a search on the Stuff website (www.stuff.co.nz) using the keywords "nitrogen", "nitrate" and "environment". They will find that there is a lot of information and a huge range of opinions around this topic. Select 10-20 of the search results and make a poster using the headings. Print and display the poster in your classroom.

Select a few articles (suitable for your students' level) that reflect a range of different perspectives on the issue. Get the students to explore the strategies of persuasive writing that are evident in the different texts. For example, students could work in groups to identify the main arguments in each article, the values expressed by the writer, and the reason the article was written. Get them to identify the persuasive language features the writers have used to make their arguments more powerful.

There is no doubt that people have benefited enormously from the use of nitrogen fertilisers and the cultivation of nitrogen-fixing plants. Lately, however, there has been a lot of interest in the harmful effects of too much nitrogen on human health and the environment. While this publication focuses specifically on the effects of excess nitrogen on water quality, you and your students may also be interested in learning about nitrous oxide (a greenhouse gas) and how it affects our atmosphere and climate.

How does nitrogen get into rivers and groundwater?

The term nitrate-nitrogen (NO_3^-N) refers to the nitrogen component of the nitrate molecule. The main sources of nitrate in New Zealand waterways are: excessive application of inorganic fertilisers, septic tanks and leaking sewage systems. Nitrate also enters waterways as a result of nitrification of ammonia from animal waste by soil microorganisms.

The term ammoniacal nitrogen (NH_4^+N) refers to the nitrogen component of ammonia (NH_3) and ammonium (NH_4^+) molecules. The major source of ammoniacal nitrogen in New Zealand waterways is faecal waste (particularly from humans and farmed animals such as sheep and cows). Ammoniacal nitrogen is toxic to aquatic life at high concentrations.

Leaching

In agriculture, the term leaching refers to the loss of water-soluble nutrients from the soil, due to rain and irrigation. If your students are familiar with magnets, remind them how the negative end of one magnet attracts the positive end of another magnet, while the negative ends of two magnets repel each other. Soil particles behave in a similar way to magnets, in that they attract and hold onto oppositely-charged nutrients while repelling similarly-charged nutrients.

Soils are composed of a mixture of sand, silt, clay and organic matter. The clay and organic matter particles have a negative charge. Ammonium (NH_4^+) has a positive charge and nitrate (NO_3^-) has a negative charge. Negatively-charged soil particles will attract and hold positively-charged nutrients such as ammonium, but repel negatively-charged nutrients such as nitrate. As a result, when water soaks through well-drained soil, positively-charged ammonium remains attached to soil particles, while negatively-charged nitrate leaches out of the soil and may be carried into groundwater or streams via surface or subsurface drains.

Compliance officer Michelle Te Maro collecting a sample from a stream on a farm. Michelle explains: "Farmers irrigate dairy shed effluent onto paddocks to help their grass grow. Sometimes their irrigation is set up close to waterways or over tiles that feed into water systems. I need to find out if the activity of irrigation has had any effect on that particular water system."

A warning sign at Clifton, Invercargill, explains that treated domestic and industrial waste is discharged to the New River Estuary at this point. Treated wastewater typically contains nitrogen, phosphorus, *E. coli*, suspended solids and other contaminants.

What's the situation in Southland?

In New Zealand, nitrogen levels in groundwater and rivers are monitored for human health and environmental reasons. The data from monitoring programmes show that nitrate levels have been gradually increasing for many years.

In Southland, groundwater is an important source of drinking water for many people and for livestock. Data from monitoring programmes shows that nitrogen contamination of groundwater is quite common.

Environment Southland also monitors nitrogen in Southland's rivers. Our data show that nitrogen is increasing at many of the sites we monitor. This is important because nitrate-nitrogen and ammoniacal nitrogen can be toxic to aquatic life.

ACTIVITIES

Interactive maps

https://statisticsnz.shinyapps.io/groundwater_quality/

Go to this website to view an interactive map of groundwater quality. Get your students to examine the map online. Which areas have groundwater nitrate levels that are higher than the standard for safe drinking water?

https://statisticsnz.shinyapps.io/river_water_quality_nitrogen/

Get your students to examine this interactive map of river water quality online.

- What do they notice?
- How does Southland compare with other regions in New Zealand?
- Which areas or rivers have worsening trends (i.e. increasing levels of nitrogen)?
- Are the results similar for nitrate-nitrogen, ammoniacal nitrogen and total nitrogen?
- Can you think of any reasons for differences?

Measure water samples

Students can measure nitrate levels in water samples by using nitrate test kits designed for fish tanks or nitrate test strips (similar to litmus paper), or you can send samples to a laboratory for testing. High-range nitrate test kits (designed to detect at least 50 ppm) can be purchased online or through an aquarium retailer for about $20.

Ways to protect water from nitrogen contamination

- If you have a septic tank, you can minimise the risk of groundwater contamination by making sure your septic tank is well maintained. As a general rule, your septic tank should be inspected once a year and pumped out every 3-5 years by a certified contractor.
- If you have a vegetable garden, you can reduce your dependence on nitrogen fertiliser by making your own compost and using other organic methods to improve your soil.
- Look after your soil microorganisms: Soil microorganisms help to release essential nutrients and perform key roles in nitrogen fixation and the nitrogen cycle. High temperatures, compaction or oversaturation can injure beneficial soil life. To promote soil microorganisms and soil health, incorporate organic matter into the soil, till as little as possible, minimise soil compaction, maintain a healthy soil pH, and use organic mulch on the soil surface.
- Protect and create more wetlands and riparian areas: Wetlands act like a sponge. They take in large amounts of water and "clean" it by processing out nutrients, including nitrogen, that are carried in the water that flows through them.
- If your drinking water comes from a well, protect your well, keep stock and chemicals away from your well and test your groundwater regularly.

ACTIVITY

Get your students to watch this video in which Dr Ross Monaghan from AgResearch describes a range of farm management practices that can be used to reduce the risk of nitrogen loss from farms into groundwater and streams: **www.sciencelearn.org.nz/videos/1758-reduce-nitrogen**

Further reading

Environment Southland

- Factsheets and groundwater maps – *www.es.govt.nz/environment/groundwater, Beacon (Maps and Data)*
- Community environmental monitoring – *www.es.govt.nz/community/community-monitoring*

LAWA

- Factsheets and maps – *www.lawa.org.nz/learn/factsheets/nitrogen*

Ministry for the Environment

- Factsheet on nitrate in groundwater – *www.parliament.nz/resource/0000238895*
- Information on looking after water in towns and cities – *www.mfe.govt.nz/fresh-water/we-all-have-role-play/towns-and-cities*

Science Learning Hub

- Factsheets, activities and an excellent interactive (animation plus video clips) to help students understand the nitrogen cycle

Website