# kNow Your Nitrates

## Overview

kNow Your Nitrates is a design challenge activity that takes a solutions-focused approach to understanding the nitrate cycle and agricultural pollution. Participants consider variables like crop variety and location, fertilizer quantity, and geographic characteristics, and use them to design an effective strategy to maximize crop yield and minimize groundwater pollution.

Source:
https://centennial.agu.org/know-your-nitrates-outreach-project-katherine-carter-national-center-for-science-education-oakland-california-usa/

## Learning Goals

1. Present participants with the relationship between agriculture, nitrogen fertilizer, and climate change/environmental impacts
2. Encourage participants to think of themselves as part of the solution to climate change

## Materials

- Stream table
    - Plastic support stand
    - 6 foot plastic hose
    - Farm animals and tractor
- Bucket that can hold at least 3 L
- Kitchen sponges with blocks and planter rows glued on (9)
- Water (~9 L)
- Neon acrylic paint (pink)
- Pipettes
- Coffee filters
- Nitrogen cycle graphic
- Plant growth graphic
- Water quality graphic
- Solo cup (to mix paint/water in)
- Colored pencils
- Dice
- Watering can
- Bucket that can hold about 5L of water

Materials that come in your kit:

- Stream table with 6 foot hose
- Support stand
- Bag of washers
- Kitchen sponges
- Coffee filters
- Neon acrylic paint
- Pipettes
- Watering can
- 4 dice
- Barn
- Table cloth

## Set-up

1. Prepare your materials
    a. Place water in stream table
    b. Display laminated handouts
    c. Mix up neon paint and water mixture in large cup- mixture should be consistent and not chunky
    d. Separate pipettes
        i. One set should be for paint mixture
        ii. One set should be clean so participants can sample water quality later in the activity
    e. Sponges should be damp, but not dripping before starting activity

## Procedure

### Short Form

1. Welcome participants and invite them to be part of an activity relating to how nitrogen affects the environment.
2. Explain that you're investigating the relationship between plant growth, nitrogen fertilizers and local waterways and you need their help
3. Give each participant a coffee filter and tell them to draw any kind of plant they like with colored pencils on it.
4. While they draw, begin introducing topics relating to fertilizer runoff, agriculture, plants etc.
    a. Also mix up and prepare pipettes with neon-water paint mixture
5. Help participants pinch and twist coffee filter into a point on one end and slide a pony bead onto the bottom
6. Have participants place their "plant" in one of the holes in either sponge. (See photo for setup details)
7. Once all coffee filter plants have been "planted" invite participants to fertilize their new plants with the neon paint and pipettes
    a. As the facilitator YOU should hold paint mixture to avoid spilling. Do not allow participants to hold the cup
    b. No Hints! It is up to them to decide how much fertilizer they use!
    c. Encourage participants to drop neon paint at the base of their plant or in the sponge, not directly onto the coffee filter.
    d. Assist with pipetting as necessary
8. Once all plants have been fertilized and have had a chance to sit for a moment participants can harvest their coffee filter plants (take the filters out of the sponge)
9. Have participants open the coffee filters and lay them on top of the growth ring handout. The pink areas indicate how much the plant has grown. More pink, more plant growth.
10. Participants should record total plant growth score on data sheet
11. Invite participants to take samples with the clean pipettes at different places in the stream table
    a. They can take samples from right under where the sponges were, in the middle of the table or at the end/well part of the table
12. Place water samples on water quality laminated handout
13. Interpret results
    a. If water is very light pink (first two color indicators), congratulate participants! Their plants grew and water quality levels are acceptable.
        i. Give out rewards as necessary and depending on age
    b. If water is medium-dark pink (any other dark color indicators), encourage participants to do the experiment again and challenge them to still grow their plants, but lower their runoff levels.

i. You can still give out small prizes for participating and/or completing the experiment again

14. Have participants record their water quality score on their data sheet.
15. If time permits, ask participants what they learned or review potential discussion topics, depending on age. Discussion should be educational but also encouraging! They are learning this information so they can empower themselves to make more environmentally conscious decisions.
16. Hand out prizes for completing the activity! (Can use mini erasers)
17. Make sure to change out water and ring out sponges between each round of the activity so that no residual neon paint remains.

## Long Form

1. Follow previous steps for short form activity
2. Include dice and watering can filled with water
3. Ask one participant volunteer to roll the die. The die will simulate variability in rainfall due to a changing climate

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| 1 | No Rain |
| 2 | Minimal Rain |
| 3 | Below Average Rain |
| 4 | Average Rain |
| 5 | Above Average Rain |
| 6 | Excess Rain |

4. Counting together, pour for one second per number rolled. Ex. 2=pour for 2 seconds, 3=pour for 3 seconds etc.
    a. *If participants roll a 1, do not add any water
5. Have participants record rainfall conditions on their data sheet.
6. After the changing rainfall has been simulated, ask participants to take water quality measurements from any of the 6 "private drinking wells" on the stream table via clean pipettes.
7. Participants record their drinking water quality score on their data sheet.
8. Total up cumulative points to see how successful they were.
9. At this point, you can bring in a discussion of health effects of nitrates in drinking water, and or/if participants have any ideas of how to alleviate/prevent groundwater contamination
10. Hand out prizes for completing activity! (Mini erasers)

*How to Score Activity*

- Scores are additive
- Plant growth, add points
- Water quality, subtract points
- Nitrates in drinking water, subtract points

*Definition of Success*

- Young kids (< 8 years old) don't require the scoring system. If kids understand that it's okay to use a little fertilizer, but not too much, then they have successfully completed the activity
- Kids (>8-13/Middle school age) should be scored based on their attempts at the activity. If they end up with a total score of 20 overall points or higher, they have succeeded!
- High school participants should be scored based on their attempts at the activity. If they end up with a total score of 30 or greater they have succeeded!

## Potential Discussion Topics

- Agricultural communities rely on fertilizer/nitrates to increase crop quality and yield-seeking – a balance between crop growth and avoiding water pollution is key
- Nitrogen cycle
- Plants require nutrients to grow (Nitrogen, Phosphorous, Potassium)
- Effects of excess nitrogen fertilizer runoff in nearby waterways
    - Eutrophication
    - Algal blooms
    - Hypoxic conditions
    - Fish kills
    - Increased turbidity
    - Pollute aquifers/private wells
- Water pollution
- Health effects/exposure to nitrates in drinking water
    - Pregnant women at high risk if exposed
    - Blue baby syndrome
- Climate change
    - Variability in rainfall
    - Increase in storm frequency and severity
    - Droughts
    - Nitrous oxides (NOx) are greenhouse gases → contribute to global warming and greenhouse effect

## Further Resources

- Khan Academy – The Nitrogen Cycle
- USDA – Climate Change
- Drinking Water Nitrate and Human Health: An Updated Review

## NGSS Standards

**K-ESS3-3 Earth and Human Activity**

Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.

**5-ESS2-1 Earth's Systems**

Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.

**MS-ESS3-3 Earth and Human Activity**

Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

**HS-LS2-7 Ecosystems: Interactions, Energy, and Dynamics**

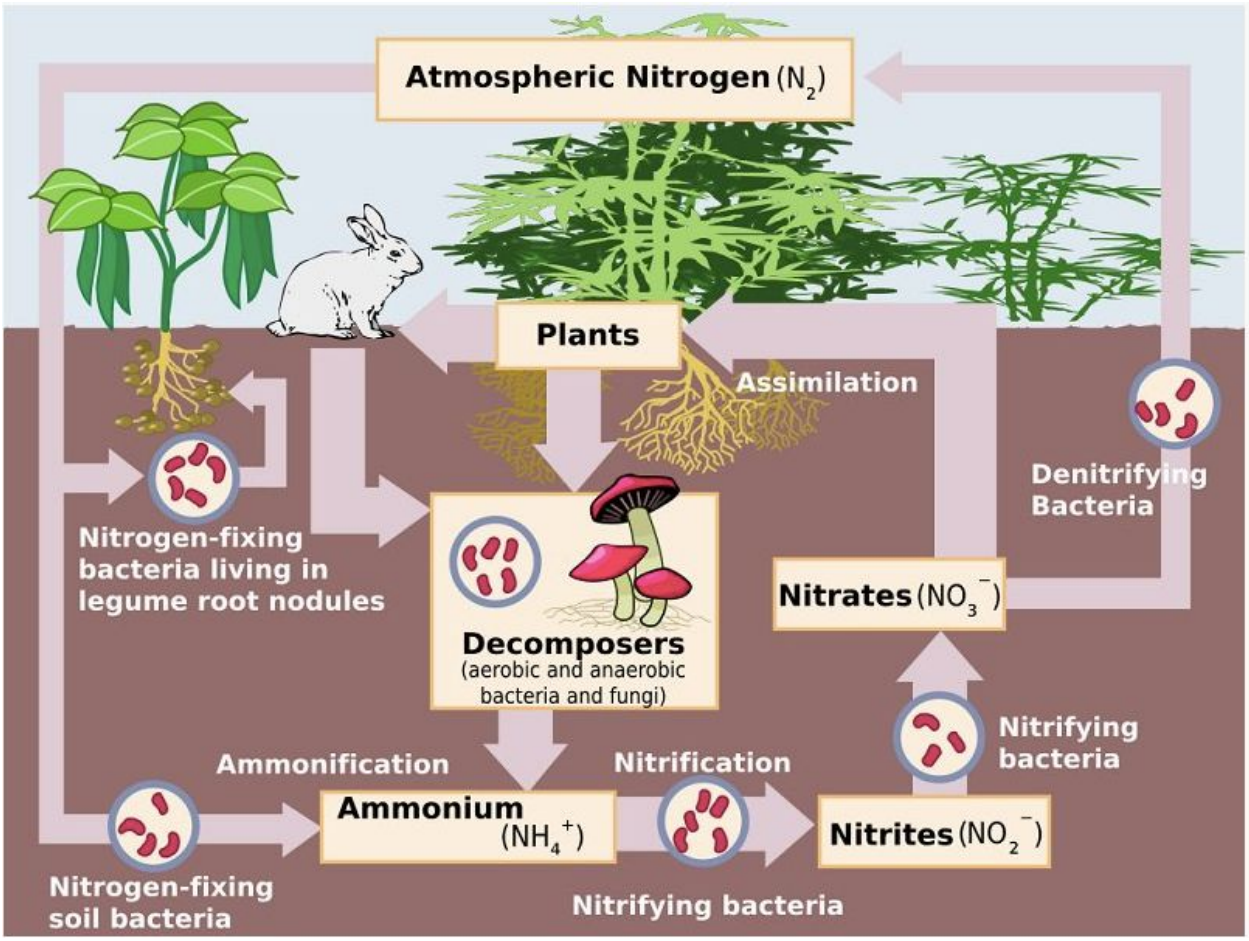
Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity

# Nitrogen FAQ

The purpose of this FAQ sheet is to supplement your background knowledge on the activity. You are not required to memorize this information, it is merely here as an additional resource.

1. What is nitrogen?
    a. Nitrogen is an element with an atomic number of 7 and is a gas at room temperature. Earth's atmosphere is 78% nitrogen, 21% oxygen and 1% argon, with trace amounts of additional elements. Nitrogen can be found as part of the building blocks of proteins and in DNA.

2. Explain the nitrogen cycle.
    a. Nitrogen Fixation
        i. Nitrogen is very abundant in earth's atmosphere. It resides in a gaseous form ($N_2$) which is not reactive and not readily accessible to plants or animals. To make it accessible, it must be fixed, via a process called nitrogen fixation. This process can be done via lightning strikes, biologically fixed by bacteria living in the soil or fixed by bacteria in the root nodules of plants. Bacteria separate the $N_2$ molecule and combine it with hydrogen to form ammonium ($NH_4$+).
    b. Nitrification
        i. Ammonium can be used by some plants, but often it is converted into both nitrates ($NO_3$-) and nitrites ($NO_2$-) by another species of bacteria that dwell in the soil and nodules of plants. This process is called nitrification.
    c. Assimilation
        i. Once the atmospheric nitrogen is either converted into ammonium, nitrites or nitrates, the plants can take it up and use these nitrogen species for their metabolic processes.
    d. Ammonification
        i. When organic matter dies (plants and animals) or animals emit waste, the organic matter is decomposed by bacteria and fungi. This process produces ammonia and ammonium and releases it back into the soil.
    e. Denitrification
        i. Denitrification occurs in oxygen-poor environments (wet soils) where anaerobic bacteria break down nitrates to access the oxygen. Gaseous nitrogen is then free and is released back into the atmosphere.




Source: Nitrogen Cycle

3. Chemical Abbreviations

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| N | Nitrogen<br>• Essential nutrient required for life |
| $N_2$ | Atmospheric nitrogen (gaseous form)<br>• Inert gas (unreactive)<br>• Comprises 78% of Earth's atmosphere<br>• Produced by denitrification |
| $NH_3$ | Ammonia<br>• Product of N fixation |
| $NH_4$+ | Ammonium<br>• Product of N fixation<br>• Forms when ammonia reacts |

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| | with water |
| $NO_2$ | Nitrogen Dioxide<br>• Form from industrial practices and combustion of fossil fuels<br>• Air pollutant |
| $NO_2$- | Nitrite<br>• Form of N that can be used by plants and animals |
| $NO_3$- | Nitrate<br>• Form of N that can be used by plants and animals |
| $NO_x$ | Nitrous Oxides. AKA $N_2O$<br>• Greenhouse gas<br>• Air pollutant<br>• Contributes to global warming |

Source: Teacher Background: Nitrogen and Climate Change

4. Glossary
    a.

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| Ammonification | Process where decomposers break down dead plants/animals and produce nitrates and ammonia. These compounds then return to the soil. |
| Assimilation | Process where plants absorb nitrates or ammonium from soil and use for metabolic activities |
| Decomposers | Organisms that break down organic matter. Usually bacteria or fungi. |
| Denitrification | Process where bacteria turn nitrates into gaseous nitrogen, which is released into the atmosphere. |
| Eutrophication | Excess nutrients in a body of water, often consisting of nitrogen and/or phosphorus. Can deplete aqueous oxygen levels and lead to fish kills. |
| Harmful Algal Blooms (HABs) | AKA red tides. Excess nutrients cause algae populations to uncontrollably grow. Can lead to depletion of oxygen, |

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| | or release of toxins in waterways. |
| N Fixation | Process where atmospheric nitrogen is converted by soil dwelling bacteria into ammonia |
| N Fixing Bacteria | Bacteria that live in plant's root nodules (often legumes). Responsible for converting atmospheric nitrogen into ammonia |
| Nitrification | Process by which nitrifying bacteria convert ammonia into nitrates and/or nitrites in the soil |
| Nitrifying Bacteria | Bacteria that convert ammonia into nitrates or nitrites |

5. Human Alteration of the Nitrogen Cycle and Climate Change
    a. Increased global movement of nitrogen and excess production of nitrogen within the environment.
    b. Anthropogenic sources of nitrogen and nitrogen species can come from: burning of fossil fuels (combustion in automobiles, power plants), fertilizer use in agriculture, industrial processes and burning of biomass.
    c. Excess nitrogen in the environment can cause:
        i. Increase in release of greenhouse gases, contributing to global warming
        ii. Increase release of car exhaust and the creation/exacerbation of photochemical smog
        iii. Eutrophication and harmful algal blooms in nearby waterways due to excess runoff of nitrogenous fertilizers
        iv. Increased incidence and severity of acid rain
            1. Causes damage to plants and increases acidity within bodies of water

Source: EPA – Sources of Acid Rain

6. At what concentration is drinking water considered contaminated or harmful for human consumption?
    a. According to the EPA, concentrations over 1 mg/L of nitrate in drinking water indicate increased inputs of nitrate due to human activity. Concentrations of 3 mg/L or greater of nitrate in drinking water are considered contaminated. And concentrations greater than 10 mg/L can cause negative health effects in sensitive populations (i.e. blue baby syndrome).

Source: Estimated Nitrate Concentrations in Groundwater Used for Drinking

7. Are private wells that are used for drinking water regulated by the EPA?
    a. No, groundwater drawn from private wells that is used for drinking water is not regulated by any federal agency. This is of concern because testing and treating pollutants falls on the private owner of the well.

Source: Estimated Nitrate Concentrations in Groundwater Used for Drinking

8. What is an MCL?
    a. MCL is a term used by the EPA which stands for Maximum Contaminant Level. This is a legal amount of substance that is allowable in a public water system under the Safe Drinking Water Act (SDWA). Units are milligrams of substance per liter of water (mg/L).

Source: U.S. EPA National Primary Drinking Water Regulations