



Excess Phosphorus in the Environment: Causes and Effects

Overview

This lesson will allow students to complete research and use critical thinking skills to learn about the implications of excess phosphorus in downstream aquatic environments as a result of conventional agriculture practices. Additionally, students will brainstorm ways to reduce, reuse, or recycle in their own lives to do their part to conserve phosphorus, which is a nonrenewable natural resource.

Key Search Words

9-12 grade, high school, earth and environmental science, environmental quality, water quality, phosphorus, precision agriculture, fertilizer, runoff, contaminants, pollution, science, technology, and society

Learning Objectives

- Students will be able to explain negative effects of overapplication of phosphorus from fertilizer on the environment, specifically downstream freshwater.
- Students will be able to explain positive environmental effects of precision agriculture.
- Students will be able to identify one way to reduce their phosphorus footprint at home and explain the process by which they could accomplish this.

Curriculum Alignment

North Carolina Essential Standards

- EEn.2.4.1 Evaluate human influences on freshwater availability.
- EEn.2.8.2 Critique conventional and sustainable agriculture practices in terms of their environmental impacts.
- EEn.2.8.4 Evaluate the concept of “reduce, reuse, recycle” in terms of impact on natural resources.

Classroom time required

- One 90-minute block period
 - 10 minute introduction discussion
 - 30 minutes for Cause and Effect Chains activity
 - 30 minutes for presentations
 - 20 minutes to reflect and write a blog post about decrease in phosphorus usage in the home
 - One 50-minute block may be appropriate
 - Decrease time allowance for Cause and Effect Chains
 - Presentations are eliminated
 - Two 50-minute blocks may be appropriate
 - Day 1: Students work on Cause and Effect Chains activity and presentations
 - Day 2: Students present and reflect on their research and write their blog post about decreasing usage of phosphorus in the home

Materials & Technology

Materials

- Construction paper - 2 different colors
- Scissors - 1 per group
- Markers - at least 2 per group
- Stapler or tape - 1 per group
- Scientific calculator
- *OPTIONAL*: Posters for presentations - 1 per group
- *OPTIONAL*: A choice earth and environmental science textbook for students to research

Technology

- Laptops - at least 1 per 2 students
 - If laptops are unavailable, print off copies of the supplemental materials about phosphorus use in the production of food and products for student use.
 - Books from the library may also be helpful for students’ research.
 - Students may use their phones for research if classroom policy allows.

- *OPTIONAL*: Projecting capabilities (if students create digital presentations)

Safety

The only potential safety concern is that students will be using scissors.

Teacher Preparation for Activity

If desired, teachers can prepare additional causes and effects to include in this activity. Teachers should create stations for students to collect their needed materials for the activity or place supplies around the room where students will be grouped. Teachers should also ensure that they have a comprehensive understanding of consequences to the actions listed in the activity as “causes,” so as to better evaluate the accuracy of students’ developed “effects.” Supplemental resources will be provided at the end of this lesson plan. If students do not have access to a personal computer, relevant books should be checked out from the library for students to use as research for the final reflection activity.

Student Preparation for Activity

If students have access to a personal computer, they should watch the following short video before class. This will provide brief background information about why phosphorus is an important resource. If students do not have access to a computer to watch this video on, the teacher should conduct a discussion at the start of class about why phosphorus is an important nonrenewable resource.

▶ Phosphorus Cycle Steps

Procedure

- Begin by either showing ▶ Phosphorus Cycle Steps or facilitating a discussion about phosphorus
 - Points for discussion:
 - Phosphorus is a nonrenewable resource stored in rocks that must be mined for use. It also enters the environment through erosion of these rocks and enters water bodies.
 - Phosphorus is a crucial building block for life (ex. DNA, plant and animal growth, ATP for energy, etc.) It is especially important in agriculture for fertilizers and animal food.
 - Phosphorus moves through the environment in water sources due to water runoff from agricultural fields.
 - Phosphorus re-enters the environment after plant or animal uptake through waste, but P also “gets stuck” in soil due to its strong potential to bond to soil particles on the molecular level.
 - What are some potential problems based on these points?
 - Potential answers: We could run out of phosphorus someday. If farmers use too much fertilizer, there is a lot of phosphorus waste. The water that runs off fields that have been fertilized lead to phosphorus contamination of downstream water sources.
 - What might be some other nutrients that move through the environment from farms?
 - Nitrogen, Potassium, Carbon
 - Give students about 2 minutes to brainstorm other ways overuse of resources might be a bad thing in the environment, and then ask for a few examples. Call on students, as you see fit, if no one volunteers to share.
- Have students break into 3 groups (or one for each “Cause” in the activity, if more were added.)
- Explain the Cause and Effect Chain activity.
 - We are creating chains of cause and effect that have to do with choices in agricultural practices - specifically having to do with phosphorus.
 - Each group will have a red (or color of choice) slip of paper with a given cause and will be challenged to come up with effects, which you will write on the yellow (or different color of choice) construction paper. Make sure to write in a way that the paper can be cut into slips for the chain.
 - Each group should have the same number of effects as they do group members. For example, if there is a group of 6 students, they should produce a chain that starts with one red link and has 6 yellow links.
 - Encourage students to use online and printed resources to research the impacts of their given Cause.
 - *EXTRA CREDIT OPPORTUNITY*: The effects linked to the cause are in sequential order.
 - Allow at least 30 minutes for students to develop their Chain and presentation. This may be extended if students are creating a more robust presentation.
- The following are the 3 Causes with example sequential Effects.
 - Cause 1 - Overapplication of phosphorus in fertilizer.
 - Excess phosphorus in runoff from farm.

- Runoff contaminates downstream freshwater bodies
- Nutrient imbalance in downstream water bodies and watershed
- Overgrowth of aquatic plants and algae due to excess phosphorus in water
- Phosphorus enters sediment and is taken up by plants to further increase growth
- Phosphorus not taken up by plants gets bound in sediments and eventually becomes legacy P
- Depleted oxygen supply in affected water bodies
- Fish deaths due to lack of oxygen
- Cause 2 - Overwatering crops that have been precisely fertilized (which means they have just the right amount of nitrogen, phosphorus, and potassium for their needs)
 - Depleted freshwater sources (aquifers, reservoirs)
 - Excess runoff carries away necessary nutrients
 - Undernourished, waterlogged crops
 - Loss of crop yield and profit
 - Erosion of soils due to excess amounts of runoff
 - Contamination of downstream water bodies with eroded sediments and nutrients from fertilizer
 - Nutrient imbalance in downstream water bodies and watershed
 - Overgrowth of aquatic plants and algae due to excess phosphorus in water
 - Phosphorus enters sediment and is taken up by plants to further increase growth
 - Phosphorus not taken up by plants gets bound in sediments and eventually becomes legacy P
 - Depleted oxygen supply in affected water bodies
 - Fish deaths due to lack of oxygen
- Cause 3 - The 4R's of precision agriculture are used (right source, right rate, right time, right place); this means that the precise amount of nutrients and water are applied to the crops.
 - Minimized fertilizer waste (and money lost to overbuying fertilizer)
 - Minimized runoff
 - Freshwater sources downstream remain uncontaminated
 - Each crop get its specific needs met
 - Optimized crop yield
 - Maximized profits
 - Implementation of additional sustainable practices
- Have students present their chains to the class. This may be completed by decorating poster boards, creating a digital presentation, or simply by pointing to links in their chain and speaking on each point.
- Some interesting points to make about each given Cause:
 - Cause 1 - Often, plants need more nitrogen than phosphorus to thrive and in the process of meeting that Nitrogen requirement, phosphorus is overapplied. (Although P is still a necessary element.) This is why we're focusing on the overapplication of phosphorus.
 - Cause 2 - Even though we think of droughts as being the worst situation for plant growth, plants can also die as a result of too much water. Overwatering is a big issue in some growing seasons because of unpredictable rain patterns. Farmers set their big irrigation systems to water their crops, but do those irrigation systems automatically know if it just poured down rain? No! Which leads us too...
 - Cause 3 - Precision Agriculture is a growing field and was an initial idea in the 1980s. Some major practices in precision agriculture include using soil sampling to know the exact amount of lacking nutrients, using soil moisture tests to measure how much irrigation might be necessary, etc. Basically, using technology (sensors) in addition to knowledge about the land and crops to be as specific as

possible with the application of fertilizers and irrigation. This is all geared towards maximizing the crop yield to feed the world's growing population.

- Now let's bring it home: How can each of us decrease our dependence on phosphorus just a little bit?
 - Give students two minutes to think about this question and then ask for volunteers to share out.
- Have students write a "blog post" or paragraph about how they will reduce use of excess phosphorus in their home. Allow students to research ways they can complete this task using the internet or print resources. The following items should be included. These blog posts should be submitted for assessment.
 - Why is it important not to use or release excess phosphorus?
 - Excess use of phosphorus requires more mining of this nonrenewable resource. (Bonus: This mining process is bad for the environment.)
 - Excess release of phosphorus has many negative effects on the environment.
 - What is one way you can reduce your household phosphorus footprint?
 - Ideas: clean up pet waste, give up meat one day per week, use phosphate-free detergents and soaps, avoid over-fertilizing the yard and sweep up excess fertilizer that winds up on the sidewalk or driveway.
 - How will you (or could you) do this in your specific home with your family?

Differentiation

- Adaptations for students with learning difficulties:
 - Provide a printed list of guiding questions for each Cause to aid in development of Effects
 - Allow students to work in pairs to develop Effects, so only half the links are required
 - Provide printed copies of the articles and pages for research
 - Actively walk throughout the classroom as students work on chain activity
 - Allow for additional wait time when asking probing questions
- Adaptations for students with gifts and talents:
 - Instead of facilitating a scaffolded discussion at the start of class, give students 5-10 minutes to research phosphorus in agriculture and environmental quality and then ask for findings. Encourage students to feed off each other's statements with:
 - "Did anyone find anything similar to John?"
 - "Did anyone read something that contradicts Jane?"
 - "Was there any more information about the effects of phosphorus on aquatic ecosystems?"
 - Have students write a one-pager to accompany the presentation on their Cause and Effect Chain, describing in words how each effect is a consequence of the previous.
 - Allow for additional wait time when asking probing questions
- Adaptations for English learners:
 - Provide language supports for the words "cause" and "effect" and scientific vocabulary with phonetic aids and definitions
 - Repeat instructions and questions multiple times using different wording
 - Allow for additional wait time when asking probing questions
 - Physically demonstrate the linking of chain together while explaining instructions

Assessment/Check for Understanding

Formative Assessment

- Group discussions at the start of class and before writing their blog post
- Questions throughout the Cause and Effect Chain activity
- Presentations of Cause and Effect Chains

Summative Assessment

- Accuracy of Cause and Effect Chains
- Blog post paragraphs about how to reduce phosphorus footprint at home
 - Are each of the required questions answered thoroughly?
 - Importance of phosphorus conservation/sustainability
 - One change that can be made to decrease phosphorus footprint at home
 - Application of this change to student's specific life
 - Alternative grading criteria is up to the teacher's discretion
- *OPTIONAL*: One-pager about students' presentations
 - Logical sequence of Effects for the given Cause
 - Informed writing – not just a summary of the group's Chain
 - Alternative grading criteria is up to the teacher's discretion

Required resources

▶ Phosphorus Cycle Steps - This video will be used as student preparation for the lesson either individually or at the beginning of the class period. It will introduce the students to phosphorus as an important nonrenewable resource.

Supplemental resources

Instructional Resources

- [Preparing for Engaging Classroom Discussions | Center for Teaching and Learning | Georgia Institute of Technology | Atlanta, GA](#)
- [Implementing Group Work in the Classroom | Centre for Teaching Excellence | University of Waterloo](#)

Background Resources on Phosphorus

- [Peak Phosphorus – Foreign Policy](#)
- [Peak Phosphorus | Generation Anthropocene on Spotify](#)
- [The Sources and Solutions: In and Around the Home | US EPA](#)
- [The Effects: Environment | US EPA](#)
- [Should You Be Worried About Your Meat's Phosphorus Footprint? : The Salt : NPR](#)

Background Resources on Precision Agriculture

- [The Four Rs of Precision Ag - United Soybean Board](#)
- [The History of Precision Agriculture | When did precision farming start?](#)

Author comments

- Depending on the general flow of your classroom, having a set of slides with promoting questions for the blog posts or writing those questions on the board might be beneficial.
- Hang chains from the ceiling around the room or in the hallway outside the classroom to display student work.
- Option to complete the activity and discussion during one class period and have presentations during a second period to allow students time to create high quality presentations.
- This lesson can be shortened by excluding presentations and just having students hang their chain up somewhere in the room when they're done linking it together.
- This lesson can be modified to encourage students' independent research by decreasing discussion time and teacher's explanations. Alternatively, the research aspect of the lesson can be minimized by more extensive teacher preparation and explanation initially, with expanded discussions
- The Cause and Effect Chain was adapted from the paper chain activity in the Bartek (2021) web article.

Sources

Bartek, Malia. (2021, April 12). *18 cause-and-effect lesson plans you'll Love*. We Are Teachers. Retrieved June 28, 2022, from <https://www.weareteachers.com/cause-and-effect-lesson-plans/>