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The Wicked Problem of Phosphate:

An Environmental Mystery

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ABSTRACT

Point source pollution is a widespread problem that can impact our water sources. In contrast to categories of pollution for which we may not know the source or cause, point source pollution can be traced back to its point of origin, such as a specific industry or sewer system. Phosphate is a type of point source pollution that contributes to eutrophication and can cause algal blooms that harm marine life and threaten clean drinking water. In this lesson, students will learn about phosphate pollutants by solving a mystery by analyzing well water data to determine the cause of a devastating fish kill.

Keywords: Phosphorus sustainability; pollution; environmental science

Phosphorus is an essential element required for the function and survival of biological organisms. It is present in soils as both water-soluble dissolved phosphorus and particle-bound phosphorus. Furthermore, it travels through soil with the aid of precipitation or flooding. Phosphorus can be transported by either surface water runoff or subsurface leaching into the soil profile. This process is aided by gravity as water travels from higher to lower elevations. The movement of phosphorus from its original source through groundwater can result in the formation of phosphorus-rich plumes in the soil. Eventually, phosphorus will enter surface and groundwater supplies.

Begin the investigation with a discussion of how phosphate can move above and below ground. Ask students to predict what happens when rain falls on fertilizer on a farmer's field. Encourage students to think about permeation as well as run off. If they mention runoff, ask them what types of substances could be transported by the water. Where do the substances go?

Do they stay on top of the ground? What is happening underneath the ground? Discuss how pollutants can move into the water table and be transported underground.

Phosphorus in the environment

Phosphorus can infiltrate the environment in high concentrations from various sources. Detergents, waste, and fertilizers are the most prevalent contaminants. In the 1970s scientists discovered that phosphate in laundry detergent was contributing to algal blooms and eutrophication. This discovery led to a nationwide voluntary ban on phosphates in detergents.

Pet waste and sewage also contain high concentrations of phosphorus that can be harmful to the environment if inadequately disposed of or if there are leaks in drainage systems. Animal farms generate vast quantities of organic waste that can be transported downstream or leached into soils. Agriculture, residential lawns, gardens, parks, and sports fields are among the many applications for fertilizers. Phosphorus from fertilizers can be washed away by precipitation or stormwater discharge if it is not absorbed by plants. These are examples of point source pollution because the source of the phosphorus pollution is identifiable. In certain instances, it is impossible to identify a singular source of pollution. This is known as nonpoint source contamination.

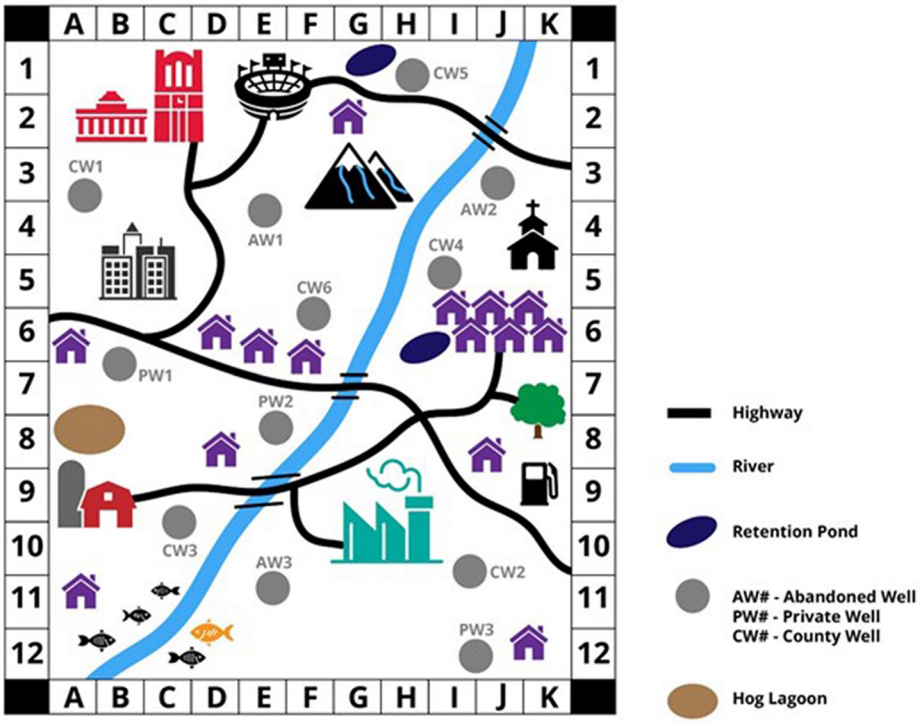
Because phosphorus is a nutrient, excessive phosphorus in water is detrimental to aquatic ecosystems because it causes algae and plants to proliferate excessively. This phenomenon is known as eutrophication. On the surface of the water, plants and algae form a dense layer that prevents fish from receiving dissolved oxygen and submerged plants from receiving sunlight. Under the surface, vegetation and animals will perish.

Investigating the mysterious fish kill

Provide the following scenario to your students: *You are a scientist who just discovered a rare fish in the local river. The National Science Foundation just awarded you a $1 million grant to research this amazing species. Unfortunately, before you can continue your study of this rare species of the fish, the news reports a massive fish kill downstream. The local chapter of the Fishkeepers Citizen Science group has been tracking an increase in eutrophication in the area that may have resulted in the fish kill. When you arrive on the scene you see that the rare fish has been part of the casualties! You must act fast to figure out what happened, so you contact the local soil and water conservation agency to test for contaminants. They determined that the fish kill was the result of excess nutrients (phosphorus). What was the main source of these contaminants? Can you help figure it out so that you can save the rare fish species?*

FIGURE 1

The community map.



Note: This lesson was adapted from *A Grave Mistake, a Project WET Curriculum and Activity* (The Watercourse and Western Regional Environmental Education Council 2003).

Task 1

Pass out the student guide sheets and instruct students to study the community map (Figure 1). Students can complete the guide sheets either individually or in pairs. The map may be projected on the board/screen and/or printed out and given to students for them to determine how the excess nutrient (phosphorus) is entering the river. Figure 2 shows the map printed and mounted on poster board, but the activity can easily be done with paper copies. Ask the students to make observations and predictions of where the contaminant could have originated and begin their investigation. Which way would groundwater flow? Notice the higher elevation and mountains in the top right. There are abandoned, private, and city wells throughout the community.

After students make their predictions, instruct them to start at the bottom of the map near the fish kill and choose three wells to sample to test their hypotheses. Contact the agency (teacher) to obtain the results of the water samples for those specific wells. Students will record the levels of each well on their handout and color code according to low, medium, or high concentrations (e.g., red = high, yellow = medium, and green = low). Ask the students to examine the levels of phosphorus in these three water samples. What does this data suggest? If students think they know the source of the contaminant, confer with the soil and water agency (teacher).

Task 2

Instruct the students to select three more wells to sample. Does this additional data confirm or refute their hypotheses? Invite students to continue to take samples and confer with the soil and water agency (teacher) to determine the source of the contaminants.

Differentiation

You may want to assign students to work in pairs if students have difficulty with directions or have the map enlarged for students with low vision.

Class discussion

Have students discuss their data and their hypotheses about where they think the spikes in phosphorus levels originated. Discuss the sources of phosphorus, levels of phosphorus, nutrient levels, eutrophication, and point pollution before revealing that the source of the contamination that caused the fish kill was a sewage spill at the university that released human wastes (excessive phosphorus and nitrogen) into the groundwater. The toxic plume moved underground, passing through the wells in the town, ending up in the river and causing the fish kill.

Other points to discuss as a class:

FIGURE 2

Exploring the fish kill on the community map.

- Natural levels of phosphate usually range from 0.005 to 0.05 mg/L, but many bodies of freshwater are currently experiencing increases of phosphorus and nitrogen from other sources. Phosphorus is not necessarily toxic to living organisms, but too much can lead to increased plant growth and algae and decreased levels of dissolved oxygen. This process of eutrophication can cause algae blooms that may also produce toxins that are dangerous to living organisms, including humans.
- In 1986, the Environmental Protection Agency established the following recommended criteria for phosphorus: No more than 0.1 mg/L for streams that do not empty into reservoirs, no more than 0.05 mg/L for streams discharging into reservoirs, and no more than 0.024 mg/L for reservoirs.

Conclusion

Having used this lesson with students, we find it supports the *NGSS (Next Generation Science Standards)*, engaging students in asking questions, analyzing data, computational thinking, and crosscutting concepts related to cause and effect and stability and change. The lesson not only teaches students about point source pollution but also emphasizes the critical role that phosphorus plays in the ecosystem. Students like using their analytical skills to solve an environmental mystery. Phosphorus has

been called a wicked problem because it is necessary for life but yet too much phosphorus causes serious pollution issues. Modern agriculture is dependent on mined phosphorus, and scientists have reported that within 25 years the world will face a serious shortage of mined phosphorus. This activity raises questions about how phosphorus moves in the environment and potential areas where we might conserve phosphorus.

DISCLOSURE STATEMENT
No potential conflict of interest was reported by the authors.

SUPPLEMENTAL MATERIAL
Supplemental data for this article can be accessed online at https://doi.org/10.1080/00368555.2024.2432892

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