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Phosphorus Behavior
In the Environment

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While manure and commercial fertilizers contain the secondary and micronutrients essential for plant growth, nitrogen, phosphorus and potassium are the most important nutrients. This publication outlines some basic information about phosphorous and its interaction in the environment.

Phosphorus

Phosphorus (P) is a naturally occurring element that exists in minerals, soil, living organisms and water. Plant growth and development requires phosphorus, like nitrogen, in large amounts. Phosphorus is essential for early root development and hastens plant maturity.

The forms of phosphorus present in soil can include organic, soluble or "bound" forms. Understanding the relationship among these forms of phosphorus is necessary to understand plants' utilization of phosphorus and the extent to which phosphorus can move within the environment. Note that phosphorus is the least mobile of the major plant nutrients.

- **Organic phosphorus** — a part of all living organisms, including microbial tissues and plant residue. It is the principal form of phosphorus in the manure of most animals. About two-thirds of the phosphorus in fresh manure is in the organic form.
- **Soluble phosphorus** — sometimes called available inorganic phosphorus. It can include small amounts of organic phosphorus, as well as orthophosphate, the form taken up by plants. It also is the form subject to loss by dissolution in runoff and to a lesser extent, leaching. The soluble form accounts for the smallest proportion of the total phosphorus in most soils.

  When fertilizer or manure (both containing mostly soluble phosphorus) are added to soil, the soil's pool of soluble phosphorus increases. With time, soluble phosphorus is transformed slowly to less soluble (less plant available) forms.

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- **Attached or "bound" phosphorus** — unavailable inorganic phosphorus. A large amount of the soil's phosphorus is bound in compounds that are formed when the anionic (negatively charged) forms of dissolved phosphorus become attached to cations, such as iron, aluminum and calcium. Attached phosphorus includes labile, or loosely bound, and "fixed," or tightly bound, phosphorus compounds.

Note that phosphorus loosely bound to the soil particles (labile phosphorus) remains in equilibrium with soluble phosphorus. Thus, when plant removal reduces the concentration of soluble phosphorus, labile phosphorus is converted to the soluble form to maintain the equilibrium.

Much of the phosphate that living organisms use becomes incorporated into organic compounds. When plant materials return to the soil, organic phosphate will be released slowly as available inorganic phosphate or incorporated into more stable organic materials and become part of the soil organic matter. The release of available inorganic phosphorus from organic sources is called mineralization and microorganisms carry it out.

How is phosphorus lost from agricultural fields?

Fields with high losses of phosphorus must have both a high source potential and a mechanism to transport phosphorus to bodies of water. Phosphorus can travel to surface water attached to particles of soil or manure. Phosphorous also can dissolve into runoff water as it passes over the surface of the field.

Leaching of phosphorus usually is not a significant concern. Soil particles strip soluble phosphorus from the water as it leaches through the soil profile. The concentration of phosphorus

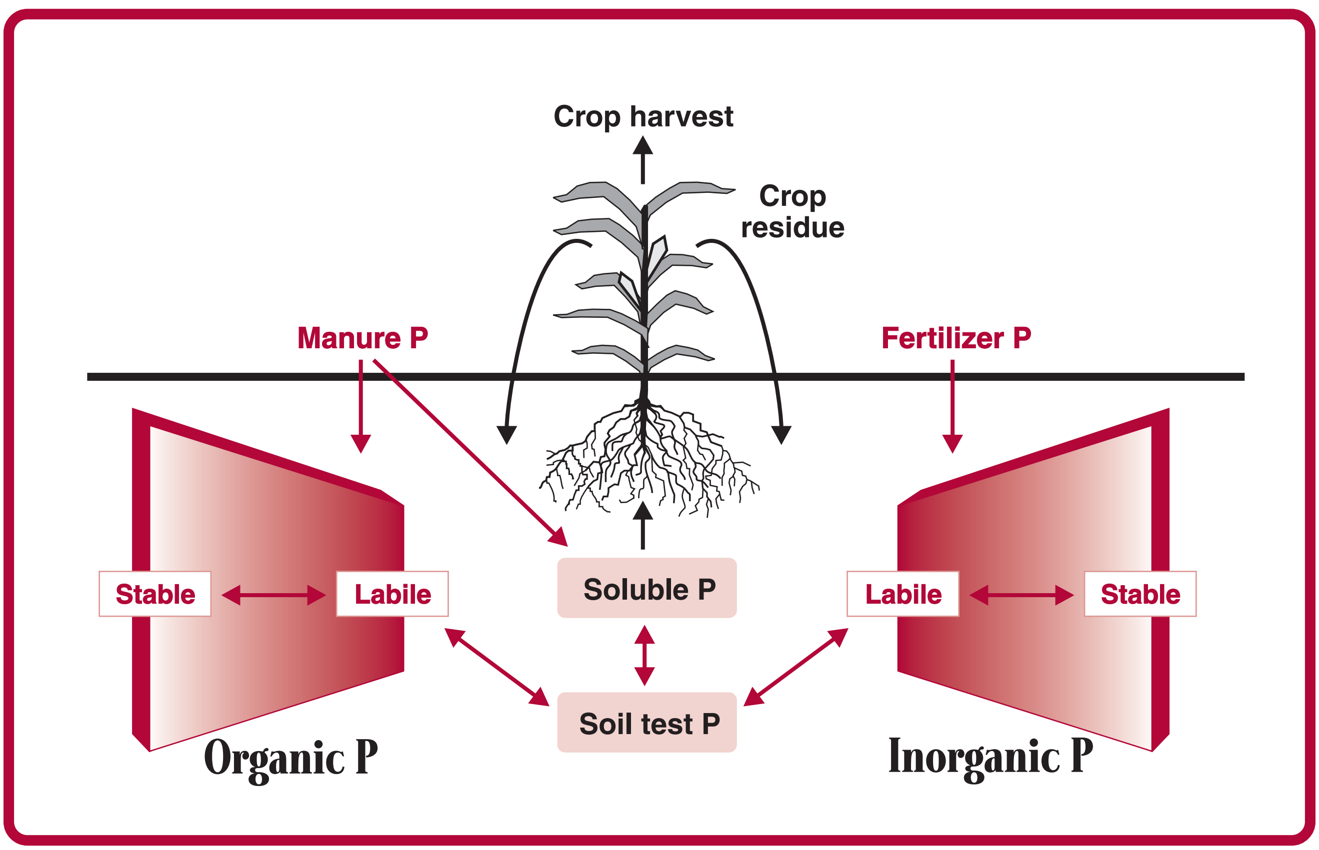

Figure 1. The phosphorus cycle. (Source: Livestock and Poultry Environmental Stewardship Curriculum)

in soil leachate is significantly less than surface runoff concentrations. However, special situations can allow higher concentrations of phosphorus into groundwater. The capacity of soil to absorb phosphorus can be overwhelmed on sandy soils or when the water table is close to the soil surface. Also, cracking in soils creates channels allowing surface water to travel directly to groundwater.

Phosphorus losses from agricultural fields can be divided into three categories: (1) flash losses of soluble phosphorus soon after application of fertilizer or manure, (2) slow-leak losses of soluble phosphorus, or (3) erosion events.

Flash losses of soluble phosphorus

Manure and commercial fertilizers have a vastly higher concentration of soluble phosphorus than soil. If rainfall runoff occurs soon after a surface application of manure or commercial fertilizer, the concentration of soluble phosphorus in the runoff can be more than 100 times greater than other runoff events. Flash losses of soluble phosphorus have high concentrations of phosphorus in a form that is readily available to aquatic organisms.

Research with poultry litter and swine manure applied to pastures shows that soluble phosphorus concentrations increase in direct proportion to increasing application rates in flash phosphorus loss events. These events occur only if rainfall runoff occurs soon after a surface phosphorus application or when phosphorus is surface applied to frozen or snow-covered fields.

An ill-timed application can contribute more phosphorus to surface water than all other processes during the course of a year.

Over time, highly soluble manure and fertilizer phosphorus on the soil surface will react with the soil, reducing soluble phosphorus in runoff. Normal levels return during the course of a month in warm soils, and longer in cold soils. Do not apply manure and fertilizer on frozen or snow-covered soils because phosphorus never has a chance to react with the soil before runoff occurs.

To minimize flash losses of soluble phosphorus:

- Apply phosphorus sources below the soil surface in a manner that does not increase soil erosion.
- Surface apply phosphorus sources during periods of the year when runoff is unlikely.
- Surface apply phosphorus sources only on fields with a low potential for runoff.
- Do not surface apply phosphorus sources to frozen or snow-covered soils.
- Maintain buffer strips around water resources.
- When possible, incorporate surface-applied P sources.

Slow-leak losses of soluble phosphorus

All soils naturally release some soluble phosphorus into surface runoff. The soil test phosphorus level of the soil affects the concentration of soluble phosphorus in runoff. Substantial evidence shows soluble phosphorus concentrations in runoff increase linearly with increasing soil test phosphorus levels. However, this linear relationship varies among soil types.

Slow-leak phosphorus losses are important because they occur in every runoff event. Because of the cumulative effect of multiple runoff events, this can be an important source of phosphorus loss.

To minimize slow-leak losses:

- Only apply phosphorus to fields that have an agronomic need for phosphorus.
- Reduce the amount of annual runoff from agricultural fields through crop selection and soil conservation practices.
- Maintain buffer strips where no phosphorus is applied around water resources.

Erosion losses

Phosphorus is almost entirely associated with soil particles. When runoff water gains sufficient energy to cause soil erosion, the amount of phosphorus lost from the field increases dramatically. Reducing or eliminating tillage to control erosion can reduce total phosphorus losses significantly.

Fine soil particles have a greater capacity to hold phosphorus than coarse particles. Unfortunately, soil erosion transports more fine particles, causing the eroded sediment to be "enriched" with phosphorus.

To minimize erosion losses of phosphorus:

- Adopt soil conservation practices to minimize soil erosion.
- Maintain buffer strips around water resources where no phosphorus is applied.

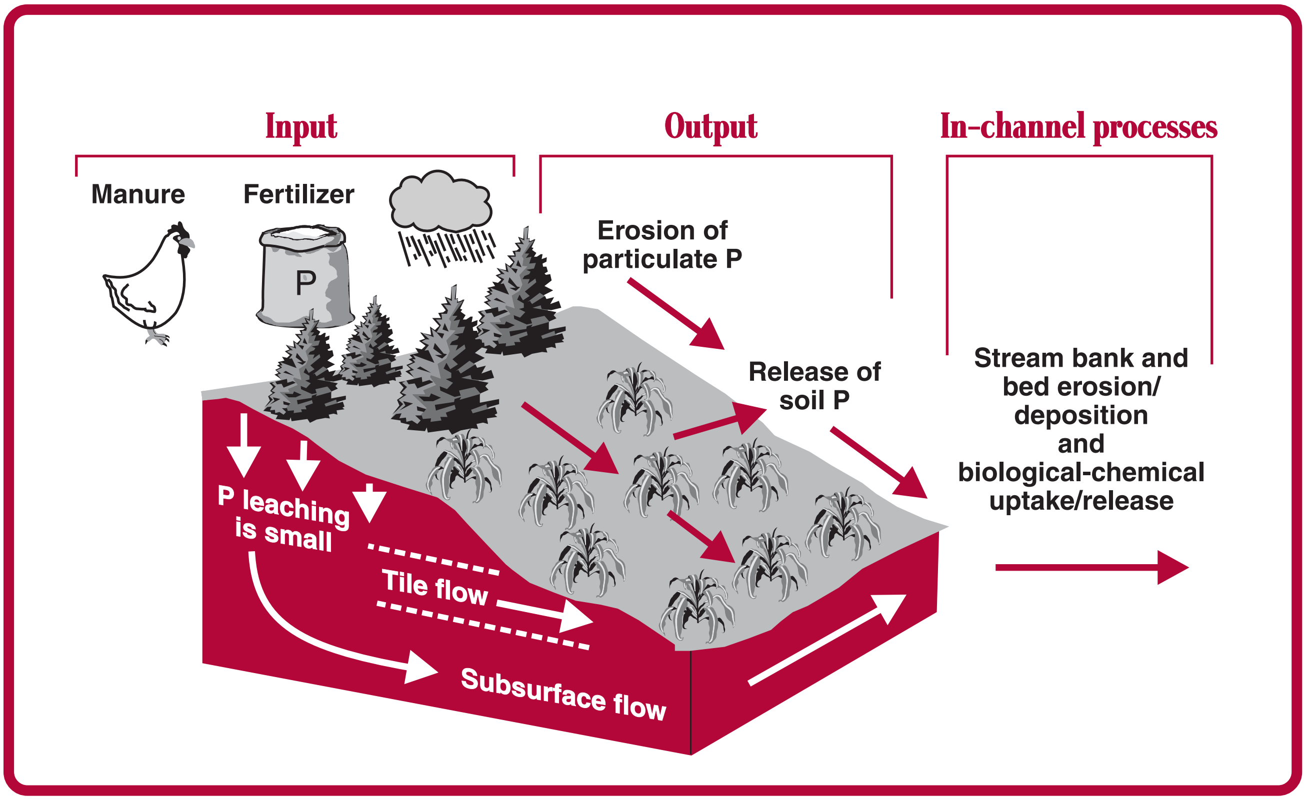

Figure 2. Phosphorous movement in the environment. (Source: Livestock and Poultry Environmental Stewardship Curriculum)

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