PHOSPHORUS

SOURCES AND MOVEMENT

AGDEX 090-4

For more information on the beneficial management practices provided to help operators minimize the loss of phosphorus into surface water, please refer to the following link: Agdex FS090-3 An Introduction to Phosphorus Beneficial Management Practices - http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/epw12912/$FILE/phosphorus-bmp-factsheet.pdf

INTRODUCTION

Phosphorus is an essential nutrient for plant and animal growth because it is a key element in many physiological and biochemical processes. Phosphorus accounts for more than one per cent of the body's mass and is the sixth most abundant element in the human body following oxygen, hydrogen, carbon, nitrogen and calcium. Phosphorus is a component of every living cell, and cannot be replaced by any other element. It occurs in many complicated compounds such as genetic molecules (DNA and RNA) and also the phospholipids, which form all cell membranes. It is an essential component of the energy-transport system in cells and is required for plant photosynthesis, which is the process that plants use to capture energy from the sun to produce carbohydrate molecules, i.e., sugars. Photosynthesis is the first step in the biological chain to produce food, feed and fibres.

Alberta soils are generally low in phosphorus for optimum crop production (< 60 ppm crop-available phosphorus in the top 15 cm). Successful crop production often requires the addition of phosphorus in the form of chemical fertilizer or manure to the soil. Phosphorus is also often added to livestock diets to ensure optimal growth. Much of the phosphorus ingested by animals is excreted in the urine and feces.

In fresh water aquatic systems phosphorus is a limiting nutrient for plant and algae growth. Only a small amount of phosphorus added to aquatic systems, creates significant plant growth. Too much phosphorus in lakes, reservoirs, rivers and streams can speed up and promote excessive aquatic plant and algae growth leading to degraded water quality. Eutrophication arises from the oversupply of nutrients. The increased growth of plant and algae can lead to oxygen depletion, release of toxins, fish deaths and offensive odours. Eutrophication can be further accelerated by human activity on the landscape, such as agriculture.

As part of the natural and essential nutrient cycling, phosphorus adheres tightly to soil, so it is commonly transported by erosion from the landscape. Runoff from agricultural systems and from land development, pollution from septic systems and sewers, manure and sewage sludge spreading, as well as other human-related activities, may increase the movement of phosphorus-containing inorganic and organic substances into aquatic systems.

The loss of phosphorus from the landscape can negatively affect the environment, with water quality being the primary concern. Within agricultural systems, beneficial management practices are used in the application and management of phosphorus in order to prevent or minimize losses. It is important to understand the source factors and the movement or transport dynamics of phosphorus.

Alberta Government

SOURCES OF PHOSPHORUS

PHOSPHORUS IN SOIL

In soil, not all phosphorus is the same. It can be either part of organic or inorganic molecules. In addition, the molecules that contain phosphorus will change in the soil through nutrient cycling. Phosphorus inputs to the soil for agricultural purposes are primarily from the application of chemical fertilizer and organic sources, such as manure.

Soil phosphorus is generally categorized into three types: soluble phosphorus, labile phosphorus and stable phosphorus.

> Soluble phosphorus is a very small part of the total soil phosphorus, but is the fraction taken up by plants. Soluble phosphorus that enters surface-water bodies is biologically available and can rapidly stimulate aquatic growth.
>
> Labile phosphorus is more plentiful than soluble phosphorus, but is still only a small fraction of total soil phosphorus. Labile phosphorus is not strongly absorbed in soil and may enter the soluble phase relatively quickly.
>
> Stable phosphorus is in forms unavailable to plants and constitutes the largest fraction of total soil phosphorus. With time, a small amount of stable phosphorus reacts chemically or biologically to become labile and soluble phosphorus. Most stable phosphorus will remain in this form indefinitely.

The vast majority of phosphorus is taken up by plants through plant roots and root hairs as they grow. Low temperatures can cause slow root growth and nutrient absorption, so plants are often unable to obtain sufficient phosphorus during cold weather, especially when seeds are germinating and the plants are small. It is beneficial to place phosphorus fertilizer in close proximity to the seed, where roots can access it, and time fertilizer and manure applications so that phosphorus is available when required for optimum growth.

For more information on phosphorus in soil please refer to the following links:
Soil Nutrient Cycling
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/epw11920/$FILE/2-1.pdf
Basic Soil-Plant Interactions
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/epw11920/$FILE/2-2.pdf

TESTING PHOSPHORUS IN SOIL

Soil testing determines how much crop-available phosphorus is present in the soil so that the proper amount of phosphorus can be applied. Phosphorus soil-test levels give a measure of the capacity of the soil to supply phosphorus to the crops. Soil testing for agronomic purposes does not measure the total amount of phosphorus in the soil because the amount of phosphorus available to plants is much less than the total amount of phosphorus. Therefore, soil testing for crop production measures only the more available forms of phosphorus. The phosphorus soil-test is used as an index and is based on historical field research trials for many soil and crop conditions. Fertilizer application plans are developed based on soil-test results.

For more information on Alberta soil and soil testing, please refer to the following links:
Soil Testing/Sampling
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex1341
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/epw11920/$FILE/3-3.pdf
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/epw11920/$FILE/3-4.pdf
Alberta Fertilizer Guide
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex3894

PHOSPHORUS IN CHEMICAL FERTILIZER AND MANURE

Fertilizers and manure are important sources of nutrients for crop production. The phosphorus in the majority of fertilizer products is present in an inorganic or soluble form that is readily available to plants. Fertilizers are a more concentrated source of nutrients, on a weight basis, than manure. The nutrient content of fertilizers is standardized and consistent. Fertilizer can be blended to make it easier to meet crop-nutrient requirements, so nutrient accumulation does not occur and optimum growth is achieved.

In manure, phosphorus is present in organic compounds as well as inorganic or soluble phosphates. Only a portion of the phosphorus in manure will be available to the crop in the year of application. The phosphorus in manure that is not used in the first year of application (i.e., residual phosphorus) will remain in the soil and be available for subsequent crops. This must be accounted for when determining subsequent crop-nutrient application rates. Soluble phosphorus in manure applied to the soil is readily available for plant use. On the other hand, organic forms of phosphorus must be released, or made plant available, through the process of mineralization, which is the decomposition of organic matter by soil organisms. This is a biological process and results in some of the added phosphorus in manure remaining in the soil for several years.

Since the phosphorus content of manure can vary considerably, this can create difficulties for accurate nutrient applications. Applying manure to meet crop nitrogen requirements generally results in the over application of phosphorus. Manure generally has a 2:1 ratio of nitrogen to phosphorus, and crops require 5 to 7 times more nitrogen than phosphorus. So when manure is applied based on crop nitrogen requirements, the crop phosphorus requirements are exceeded, and phosphorus will subsequently accumulate in the soil, thereby increasing the risk of phosphorus loss via surface runoff or leaching (downward movement of phosphorus through the soil profile). Obtaining nutrient analysis of manure samples can help to manage the use of manure as an available nutrient source.

For more information on phosphorus in manure please refer to the following links:
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/epw11920/$FILE/2-3.pdf
Manure Sampling
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/epw11920/$FILE/4-2.pdf
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/epw11920/$FILE/4-3.pdf

PHOSPHORUS IN WATER

In water, phosphorus can be found in solution, attached to suspended or settled sediments as well as in aquatic plants and animals.

In low nutrient freshwater systems, aquatic plant growth, including algae, is usually limited by low phosphorus levels. Adding small amounts of phosphorus to water dramatically enhances the growth of algae and other plants. Alberta waters are naturally nutrient rich, so a small amount of phosphorus can speed up eutrophication. In recent decades, abundant algal growth has made the water in some lakes in Alberta unpleasant or unsuitable for drinking and swimming.

In streams and lakes, phosphorus can be found in various forms:

Total dissolved phosphorus is dissolved inorganic and organic phosphorus.

Dissolved reactive phosphorus (DRP) is the portion of total phosphorus immediately available for plant growth. High concentrations may be a water quality concern. Runoff from manured fields tends to have relatively high concentrations of DRP.

Particulate phosphorus is also known as sediment phosphorus. This form of phosphorus can be in suspension or in lake sediments. It is defined as follows:

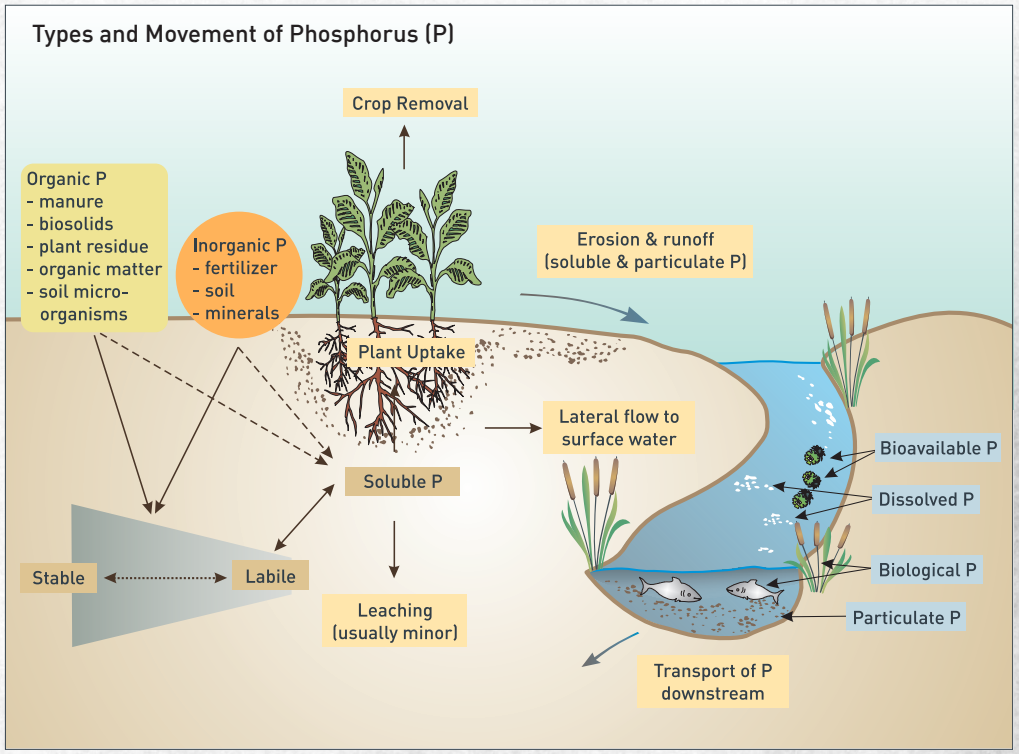
Insoluble phosphorus compounds, formed by reactions between phosphate and minerals in solution, or

Phosphorus attached to sediments or soil particles.

Bioavailable phosphorus is the portion of phosphorus in the system that is readily available or rapidly taken up by algae.

Biological phosphorus is stored by plants, insects, mollusks, and fish in aquatic systems.

IN STREAMS AND LAKES, PHOSPHORUS CAN BE FOUND IN VARIOUS FORMS.



For more information on phosphorus in water please refer to the following links:

A Primer on Water Quality
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/wat3345
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/wat3347

Alberta Soil Phosphorus Limits Project
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag11864

Phosphorus Mobility Study
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag2408

Alberta Environmentally Sustainable Agriculture Water Quality Project
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/irr12914

Water Quality in Alberta Irrigation Districts
http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/irr14080

MOVEMENT OF PHOSPHORUS

Phosphorus occurs in many chemical forms in soil and water. However it is generally not very mobile in the soil; unlike some nutrients such as nitrogen. Also phosphorus does not have a gaseous form that moves through the atmosphere like the other essential nutrients, such as oxygen, hydrogen, nitrogen, carbon and sulphur.

Phosphorus is readily sorbed by soil particles and generally does not leach through the soil profile unless soil phosphorus levels are excessive, and then it can migrate downward with water movement. Generally, over-applied phosphorus tends to accumulate and stay near the soil surface, and this can increase the risk of phosphorus loss through soil erosion and surface runoff.

Phosphorus moves from the landscape attached to soil particles carried by wind or water and in dissolved forms carried by surface-water runoff. Particulate phosphorus (PP) refers to all forms of phosphorus sorbed by soil particles and organic matter. Dissolved phosphorus (DP) refers to forms of phosphorus dissolved in the surface runoff. Once mobile, phosphorus can be re-deposited elsewhere on the landscape or be carried to surface-water and potentially degrading water quality.

The factors affecting phosphorus movement and loss from the landscape can be divided into transport, source and management factors. Transport factors include the mechanisms by which water moves within the landscape. These are topography, surface cover (i.e., vegetation), the potential and volume of surface runoff for a given area. Source factors include the presence of phosphorus as well as where the phosphorus originates; plant material, manure, fertilizer or soil. Management factors include soil phosphorus levels, type of vegetation, method, timing and placement of phosphorus applied via manure and fertilizer, method and timing of tillage, livestock feeding, bedding and grazing practices, and the condition of grassed waterways, stream banks and channel beds.

THE MAJORITY (>80%) OF THE RUNOFF IN ALBERTA COMES FROM SNOWMELT.

The movement of phosphorus is closely tied to the interaction of phosphorus to the runoff and the amount of surface water flowing over the site. The greater the water flow through or over an area, the greater the erosion potential or opportunity for phosphorus to be dissolved and carried by the water, increasing the risk of soil and phosphorus movement from the site.

Runoff of water either across the soil surface or via subsurface flow can contain significant concentrations of DP. As runoff water (rainfall or snow melt) moves across the soil surface, the water interacts with plant material and a thin layer of topsoil. During this process, phosphorus is extracted from the soil and plant material and dissolved in the water. The removal of phosphorus from plant residue may account for differences within and among watersheds and seasonal fluctuations in phosphorus movement.

For more information on the movement of phosphorus and minimizing phosphorus losses please refer to the following links:
Factors Affecting Runoff Nutrient Losses
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/epw11920/$FILE/8-1.pdf
Alberta Phosphorus Watershed Project
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/irr14541

Concentrations of DP in subsurface flow are usually low because the phosphorus-deficient subsoils sorb much of the soluble phosphorus contained in the water percolating through the soil profile. Exceptions may occur in organic, permeable coarse and waterlogged soils with low ability to retain phosphorus.

Dissolved phosphorus can also be lost from standing vegetation (e.g., crop residue, alfalfa, native prairies) via spring snowmelt because phosphorus contained in the plant tissue is released due to breakdown of plant cells during freezing and thawing.

The risk of phosphorus loss occurs when the transport and source factors interact. The presence of phosphorus is not a risk unless there are mechanisms that can cause it to be lost. The combination of transport factors and source and management factors will determine the amount of phosphorus that moves from the landscape. Flooding, for example, creates a high risk for transport potential as flood water interacts with the soil being flooded. The risk of phosphorus loss in flooded areas is compounded by the soil conditions and management practices. If the site was manured with no incorporation or the site was used for livestock feeding with no incorporation prior to flooding, the risk of phosphorus loss is greater than if there were no or limited sources of phosphorus on the site.

The loss of phosphorus from the landscape can be enhanced by a variety of human activities, including agriculture. Examples of phosphorus loss due to agricultural activities can include increasing the erodiblity of soil, surface-applying chemical phosphorus and organic fertilizers with no incorporation, accumulation of phosphorus in the soil, poor siting of livestock facilities, and livestock access to riparian areas. Fortunately, steps can be taken to improve agricultural practices that can minimize soil and nutrient losses from agricultural landscapes.

A sites' position on the landscape and location within the watershed will affect the amount of run-on and runoff water the site will be exposed to. This creates the sites' potential for the transport of soil and phosphorus loss. How that land is managed or used will determine its phosphorus contributing potential. By understanding the transport potential of the site, it is possible to either manage the transport or source and management factors to minimize the potential for soil and phosphorus loss from a site.

THE RISK OF NON-POINT SOURCE RUNOFF IS GREATEST FOLLOWING SNOWMELT AND RAINSTORMS.

MANAGING PHOSPHORUS TO MINIMIZE LOSSES

How phosphorus is being lost influences the management options available to mitigate or reduce those losses. The movement of nutrients such as phosphorus can be classified as either from a point-source (single identifiable source) or a non-point source (multiple and not always identifiable source).

Point-source is the release of contaminants through the outlet of a single conduit, such as a pipe or ditch. Because point-source pollution is usually concentrated, it is the most significant contamination source, but it can be the easiest to resolve. For example, runoff ponds or catch basins can be constructed to capture and contain point-source runoff.

Non-point source refers to contaminants that do not originate from one location. Instead, the pollution comes from many diffuse sources or from the broader landscape. Examples can include runoff or erosion from agricultural land. The concentration of contaminants from non-point sources is generally very low. Controlling non-point source contaminants tends to be very difficult and usually requires a change in land-management practices.

The most effective methods of minimizing phosphorus losses will be to evaluate the site to determine which transport, source and management factors are interacting. Once those factors are identified, changes in management can be adopted to minimize the loss of soil or

For more information on Managing Phosphorus please refer to the following links:

Manure Management
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/epw12912
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex929
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/epw9926
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/epw11920

phosphorus from a site. Controlling erosion, for example, is of prime importance in minimizing PP movement, especially in fertile agricultural landscapes. Strategically placed and properly designed filter strips have been shown to reduce erosion and PP movement. The strips must be level to prevent channelization of surface runoff water and sufficiently wide enough to effectively filter out contaminants in the runoff. Other measures to reduce the potential for phosphorus movement by erosion and runoff include terracing, contour tillage, cover crops and impoundments or small reservoirs.

Changing manure application practices (timing, frequency, location and method of incorporation) to minimize the opportunity for runoff water to interact with the manure is key in minimizing DP from a site. Alternatively relocating livestock facilities or livestock feeding areas to avoid areas of flooding or run-on and runoff are also effective at minimizing the loss of phosphorus from a site.

There are some guiding principles that apply to many of the phosphorus management challenges encountered in most agricultural operations.

> Divert clean water away from nutrient sources such as manure – keep clean water clean with eavestroughs and berms.
>
> Capture and manage nutrient rich runoff by reusing the material on crops.
>
> Reduce volumes and concentrations of manure exposed to runoff where possible.
>
> Manage soil testing of phosphorus levels, manure and fertilizer application rates; know what you've got in the soil – using nutrient management planning, soil and manure testing.
>
> Apply nutrients using 4R stewardship principles – right source, right rate, right time and right place - add what you need, when required, where required, and in the most suitable form.
>
> Keep what you've got – keep phosphorus in the soil and keep your soil on the land through soil management, soil erosion control and the establishment of riparian areas to prevent phosphorus from entering surface water.

APPLY NUTRIENTS RIGHT!

RIGHT SOURCE
RIGHT RATE
RIGHT TIME
RIGHT PLACE

FOR MORE INFORMATION

For more information, email duke@gov.ab.ca or call the Ag-Info Centre toll free at 310-FARM (310-3276).

To obtain more copies of this information summary, download a PDF version at www.agriculture.alberta.ca/manure.

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