INTRODUCTION

Phosphorus (P) is a naturally occurring element and is a key nutrient for the growth of crops, plants and algae. It occurs in many chemical forms.

In terrestrial ecosystems such as woodlands or croplands, phosphorus can be found on soil particle surfaces as well as in soil minerals, soil solution, plants and animals.

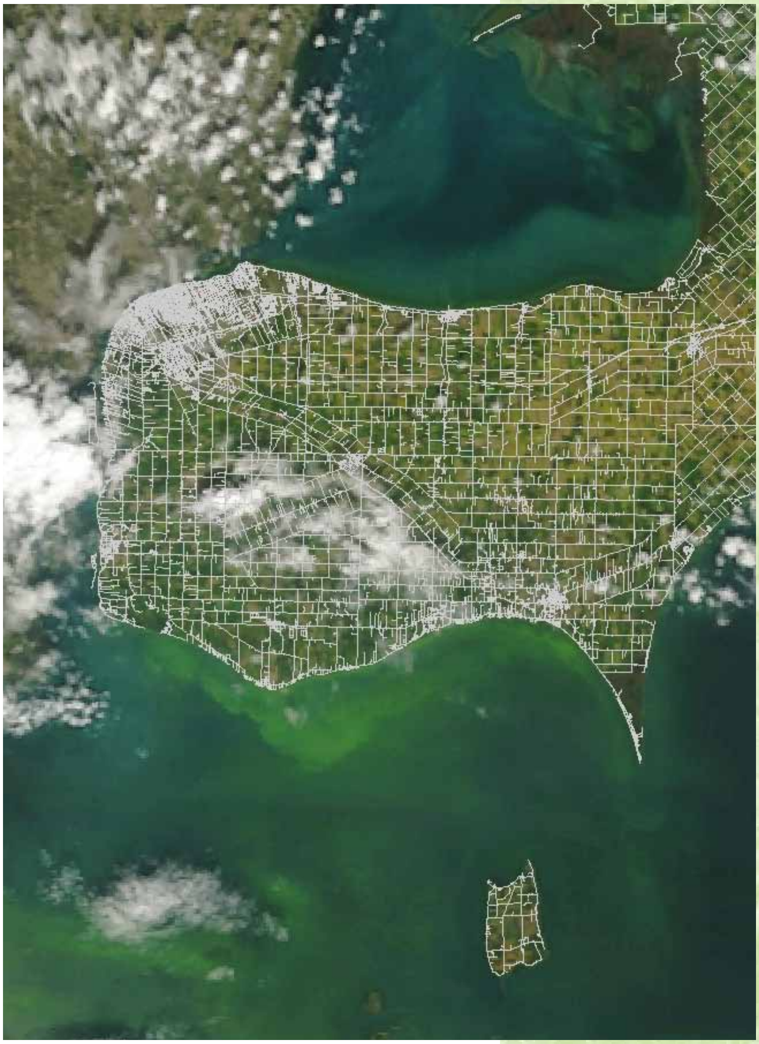
In aquatic ecosystems such as watercourses or lakes, phosphorus can be found in solution, attached to suspended or settled sediments, and in aquatic plants and animals.

Besides its natural presence in ecosystems, phosphorus appears in several forms as part of human-driven industrial, urban and agricultural activities. Excessive loss of phosphorus from these activities to the natural environment is harmful to aquatic ecosystems. In fresh waters, elevated phosphorus levels can:

- reduce oxygen in lakes, ponds and rivers – harming cold-water fish
- accelerate aquatic plant growth and create algal blooms – degrading the quality of irrigation water, contaminating livestock water, fouling beaches, impairing municipal and private drinking water supplies, and increasing the cost of treatment.

Everyone can take action to reduce phosphorus loss to the environment. This booklet is intended to help readers:

- understand the sources and forms of phosphorus created by agricultural activities
- learn about the impact of phosphorus on aquatic ecosystems
- recognize opportunities to implement sustainable agricultural practices (best management practices or BMPs) that can reduce phosphorus losses from agricultural sources.



Phosphorus contributes to excess algal and aquatic plant growth in parts of the Great Lakes. Note the green tones in Lake Erie and Lake St. Clair in this photo.

SOURCES OF PHOSPHORUS POLLUTION

POINT AND NON-POINT SOURCES

Phosphorus pollution comes from *point* and *non-point* sources. A point source means the pollutant enters the water body from a specific location. A non-point source is not so easily identifiable, as it comes from diffuse and variable points across the landscape.

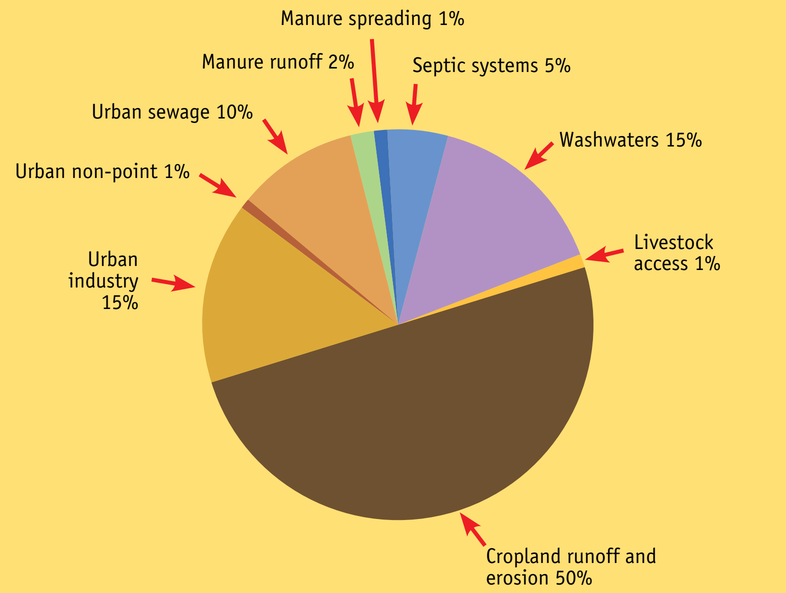
In urban areas, point sources of phosphorus pollution include industry and wastewater treatment plants. Urban stormwater runoff is considered a non-point urban source.

In rural areas, the majority of phosphorus loadings come from non-point sources, such as cropland erosion and runoff to surface waters – although this will vary from watershed to watershed. Potential agricultural point sources include poorly managed:

- washwaters from milking centres
- nutrient solutions from greenhouses
- runoff from livestock yards and stored manure.

Phosphorus is an essential nutrient in natural ecosystems, and is essential for crop growth and livestock production.

SOURCES OF PHOSPHORUS ENTERING RIVERS AND LAKES IN AN ONTARIO WATERSHED



Source: Fanshawe Reservoir Clean Up Rural Beaches Study

Every watershed is unique. This graph shows phosphorus contributions from different sources to a watershed in southwestern Ontario.

Soil erosion and nutrient runoff can promote algae and other aquatic plant growth, which decrease oxygen in surface waters. This degrades water quality for drinking, recreation, and fish habitat.

Greenhouse operations use nutrient solutions to fertilize flower and vegetable crops. Proper treatment and storage of used nutrient solutions will reduce the risk of phosphorus runoff to surface waters.

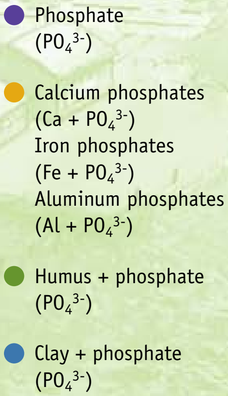
The risk of phosphorus pollution of surface water can be reduced with BMPs for applying manure, composted material, biosolids, and mineral fertilizers.

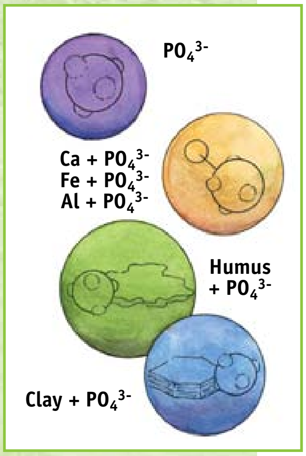
PHOSPHORUS ENRICHMENT IN SURFACE WATERS – LAKES, RIVERS AND STREAMS

There are two ways to look at phosphorus in the environment: phosphorus in surface waters and phosphorus in the soil. In unpolluted freshwaters, aquatic plant growth, including algae, is usually limited by the low level of phosphorus. When phosphorus is added to water, more algae and other plants are able to grow. In recent decades, abundant algal growth has made the water in some lakes and rivers in Ontario unpleasing or unsuitable for drinking or swimming.

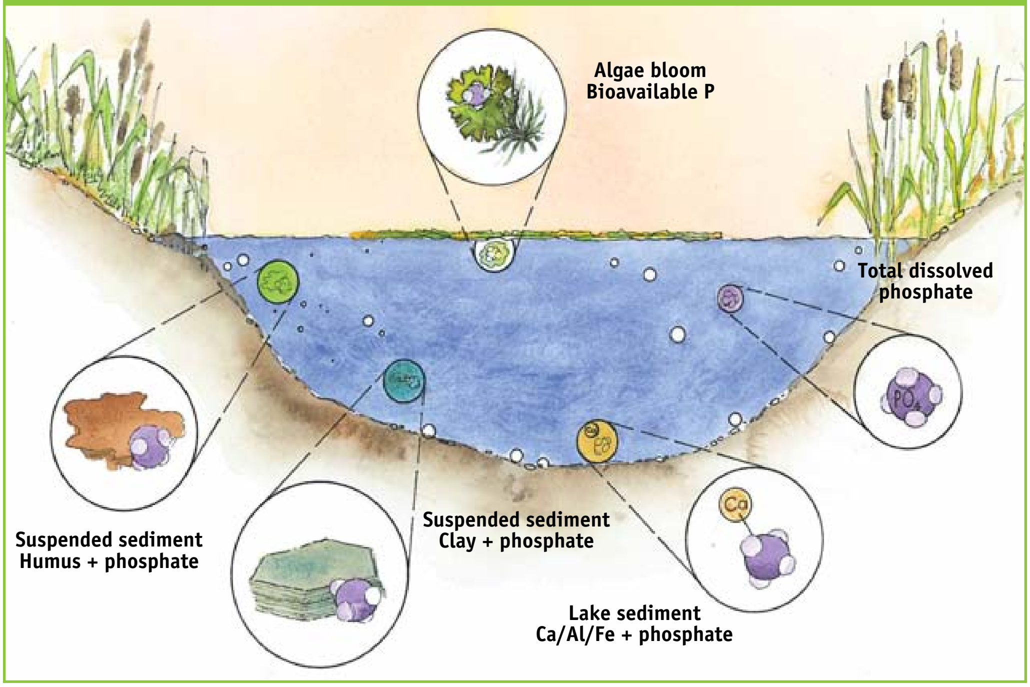
Eutrophic is the term used to describe the condition of nutrient enrichment when aquatic plant growth becomes excessive. One of the key concerns of eutrophication is the impact on oxygen levels. High nutrient levels cause rapid growth of algae, which can form large blooms. Algae grow quickly, but each alga is short-lived. The dying mass of algae adds organic matter, which then decays. As the bacteria consume this glut of organic matter, they also consume dissolved oxygen in the water.

Like us, fish and other aquatic organisms require oxygen. Trout, salmon, and aquatic insects such as mayfly, stonefly and caddisfly are particularly sensitive to low oxygen levels.





FORMS OF PHOSPHORUS IN A LAKE ENVIRONMENT



Phosphorus is dynamic in surface water and constantly cycles among the various forms, unless trapped in deep sediments on the lake bottom.

PHOSPHORUS IN SURFACE WATERS

There are three forms commonly used to describe phosphorus in runoff, streams and lakes.

1. **Total dissolved P** (TDP), often called dissolved P, is defined as P that passes through a 0.45-micron filter. Total dissolved P is primarily orthophosphate (PO_4^{3-}) dissolved in water, but also may include some dissolved organic P. In some cases, only the orthophosphate component of total dissolved P is reported and is called dissolved reactive P (DRP).

2. **Particulate P** (PP) is also known as sediment P. This form of P can be in suspension or in lake sediments. It's the difference between total P (see below) and total dissolved P, and is defined as:

   - insoluble P compounds, formed by reactions between phosphate and minerals in solution – see gold spheres labelled calcium (Ca), iron (Fe), or aluminum (Al) phosphate (PO_4^{3-})
   - P attached to sediments – see blue spheres labelled clay + phosphate (PO_4^{3-}), and
   - organic P, attached to the surface of or incorporated into organic compounds, including living organisms – see green spheres labelled humus + phosphate (PO_4^{3-}).

3. **Bioavailable P** (BAP) is also known as algal-available P, and referred to as algae bloom/bioavailable P in the illustration. It is defined as the portion of total P that is available to algae. It includes all of the total dissolved P and the portion of particulate P that algae are able to extract.

Bioavailable P is a measure of how much P from different sources will affect water quality.

Particulate P is less available in aquatic systems in the short term. In the long term, under conditions of low BAP concentration in the water, more of the particulate P can be released.

Total P (TP) is the total of dissolved P and particulate P in a water sample. (TP = TDP + PP).
Bioavailable P = TDP and some of PP

Phosphorus is dynamic in surface water and constantly cycles among the various forms, unless trapped in deep sediments on the lake bottom.

See the next page for a description of how these forms of phosphorus interact in surface waters.

While not all forms of phosphorus are equally available to aquatic life, they are all of concern for aquatic ecosystems. In general, the more soluble forms of phosphorus are immediately available to aquatic organisms, while phosphorus bound to sediment or precipitated as insoluble minerals has a slower, but longer term, impact on water quality.

Conversion of particulate P to a bioavailable form is affected by:

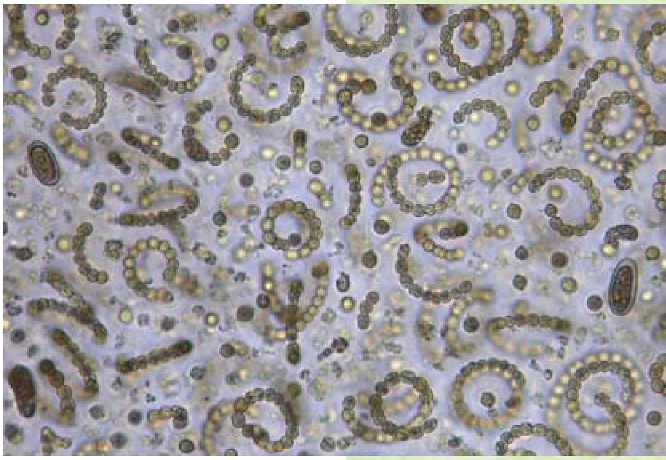
- phosphorus content of the particles and the surrounding water
- water pH and alkalinity
- size of the particles
- amount of sediment in the water – a greater proportion of P will detach from the sediment in clean water than muddy water.

When there is a shortage of dissolved P, algae can produce the enzyme *phosphatase*, which helps release more of the particulate P into forms the algae can use. This is why water quality does not always immediately improve after sources of P are reduced. The sediment-bound P continues to be released, until it is depleted or flushed downstream.

Molluscs and other aquatic life-forms filter water for nutrients. Shell tissue contains high levels of phosphorus and calcium. These organisms act like a living P-savings account, and can store large amounts of bioavailable P. As the shells break down slowly, P is recycled.

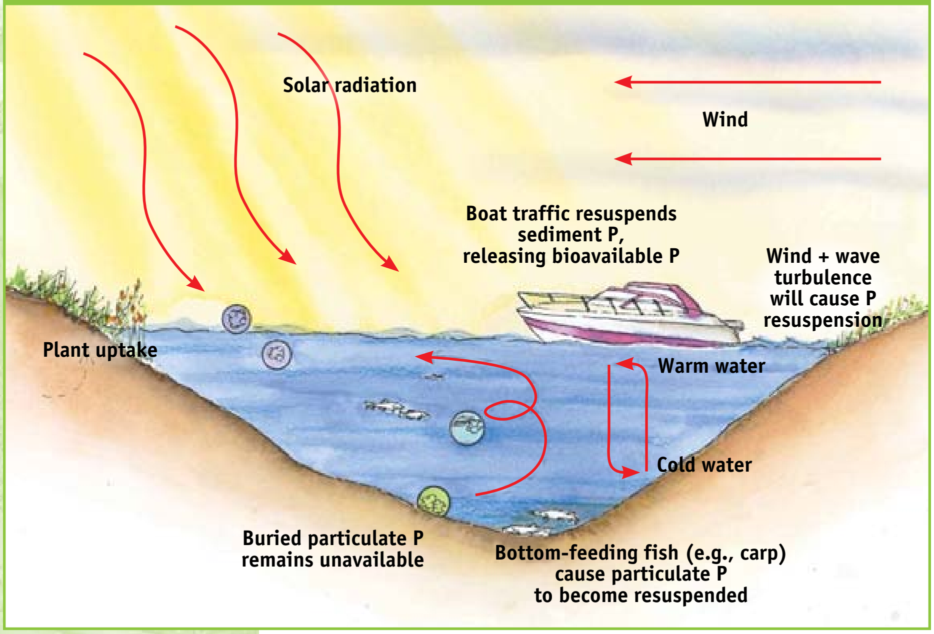
However, the mussels' feces, which break down quickly near-shore, are high in bioavailable P. Mussel feces can also be high in dissolved P. The invasion of exotic species like this zebra mussel has contributed to the reduction of P in the deep waters of the Great Lakes, while increasing P concentrations near the shore.

Excessive levels of phosphorus can lead to increases in levels of cyanobacteria (also known as blue-green algae) in surface waters. Blue-green algae produce a wide range of toxins that are harmful to animals and humans.



Available P for algae does not decline as quickly as reductions in P input, due to buffering by natural processes.

LIFE CYCLE OF PARTICULATE P IN SURFACE WATERS AND SEDIMENTS

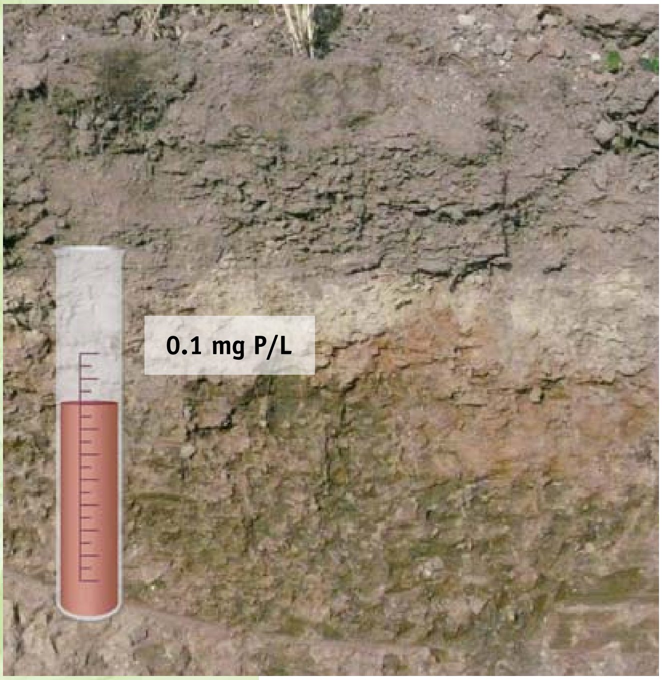


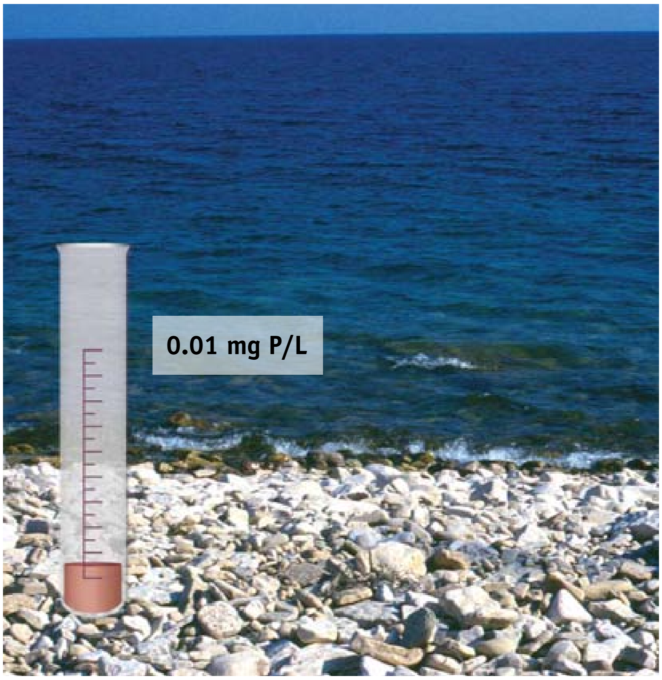
In some undisturbed aquatic ecosystems, particulate P will remain relatively unavailable. Particulate P is trapped in layers of buried sediment, or the chemical form may be relatively insoluble or not highly reactive with other aquatic chemicals.

This can change when aquatic ecosystems are disturbed. Wind and waves in shallow lakes, motorboat traffic, and bottom-feeding fish such as carp cause resuspension of particulate P, driving the reaction to release BAP. Typically lakes "turn over" or mix in the spring and fall. Turnover occurs when the water's temperature and density are the same at all depths, which allows it to mix freely. P can then be brought up from deeper water.

Depletion of oxygen in the bottom waters can cause the release of dissolved P from iron phosphates in the sediments.

In the short term, dissolved P is of greatest concern because it's immediately available to algae. However, because particulate P can transform into dissolved P under certain conditions over time, the larger amount of sediment-bound P can also cause excessive aquatic plant growth (eutrophication).





Concentration of phosphorus in soil solution of a fertile soil for plant growth is about 0.1 mg P/L. Acceptable concentrations in lake water are usually less than 0.01 or 0.02 mg P/L, depending on the natural phosphorus concentration of the system. Small losses from cropland can have large impacts on lake water quality.