# MICROORGANISMS

## Role of Microorganisms in Phosphorus Cycling

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### INTRODUCTION

***Phosphorus,*** like carbon and nitrogen is an essential element in all living systems.

Phosphorus

- is required for the synthesis of nucleic acid molecules (DNA, RNA).
- is a vital component of the biological energy molecule adenosine triphosphate (ATP)
- as hydrophilic phosphate groups, are in phospholipids, essential components of cell membranes

Under normal conditions, phosphorus is not an abundant component of the ecosphere. When it is present, it may not be in a form that is readily available for assimilation by organisms since its availability is restricted by its tendency to precipitate in the presence of metals such as calcium, magnesium and ferric iron ions at neutral to alkaline pH. As an essential element, therefore, it often limits the growth of primary producers such as algae, other aquatic plants, cyanobacteria and photosynthetic bacteria.

A large inert reservoir of phosphorus exists as tertiary phosphate rock, such as apatite; however, this reservoir is being increasingly tapped by the fertilizer industry. During the manufacturing process, the insoluble tertiary phosphate of apatite is converted by acid treatment into the more soluble secondary and primary "superphosphates". Eventually, much of this phosphate finds its way into various freshwater and marine ecosystems where it promotes eutrophication.

***Microbial transformations of phosphorus*** also occur. Most phosphorus transformations mediated by microorganisms involve the mineralization of organic to inorganic phosphates (a process also referred to as "decomposition") or the conversion of insoluble, immobilized forms of tertiary phosphate into soluble, mobile primary phosphates that are more readily used by organisms. Some microbial transformations include the following.

- Mineralization of ***organic to inorganic phosphate*** involves processes catalyzed by ***phosphatase*** enzymes, which are specifically involved in this conversion. Many microorganisms produce these enzymes.
- In addition, some bacteria and fungi produce ***phytase***, an enzyme which releases soluble inorganic phosphate ($PO_4^{3-}$) from ***organic phytic acid*** (inositol hexaphosphate).
- Some heterotrophic micro-organisms are also capable of solubilizing phosphates combined with calcium or magnesium (Atlas & Bartha 1998). These soluble forms can now be readily taken up by plants, algae, cyanobacteria, and autotrophic bacteria and assimilated into organic cellular components (DNA, RNA, ATP, etc.).

***Phosphatase enzymes*** are present in all organisms but only bacteria, fungi, and some algae are able to secrete them outside of their cells. As exoenzymes, they participate in the dissolution and mineralization of organic phosphate compounds in the environment (Jones 2002).

Without phosphatase enzymes, the presence of inorganic phosphorus would be limited to external sources, such as fertilizers, and primary productivity would be limited and dependent on these external sources. Phosphate would remain sequestered in cell matter and unavailable for producers. **The enzymatic activity of microbial communities is critical for the proper cycling of phosphorus within an ecosystem.**

Although phosphate concentrations exhibit seasonal fluctuations that are associated with algal and cyanobacterial blooms, primary productivity in many aquatic habitats is phosphate limited. The introduction of high concentrations of phosphates from wastewater treatment plants, livestock operations, and heavily fertilized agricultural land, however, provides an excess of phosphate promoting uncontrolled algal growth which eventually leads to eutrophication.

Although the annual input of phosphorus ~(6,600 tonnes) into Lake Winnipeg from anthropogenic sources (sewage, crop fertilizers, livestock manure etc.) has been estimated (LWSB 2005), **the amount contributed through microbial activity (i.e. mineralization) had not been previously studied**.

This study found that phosphatase activities (both acid and alkaline) were higher in the sediments of the North basin than in the sediments of the South basin. It is possible that microbial phosphatase activity remobilizes sediment phosphorus in the North basin thus releasing a significant amount of inorganic phosphorus into the lake and as a result, contributes toward primary production and eutrophication.

## METHODS

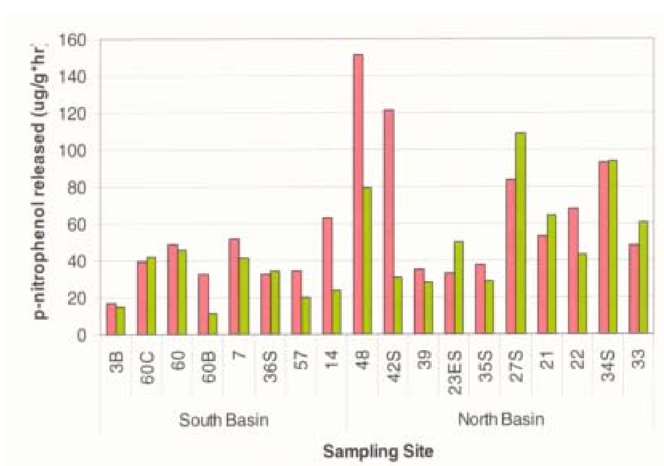
Eighteen sediment samples were obtained during September and October 2004 and subjected to a number of microbial examinations, including acid and alkaline phosphatase activities.

## RESULTS

The figure below indicates that ***acid phosphatase*** activity was highest in the sediment in the North basin (site 48, 151.3 µg p-np/g*hr) and lowest in the sediment in the South basin (site 3B, 16.8 µg p-np/g*hr).

The greatest amount of ***alkaline phosphatase*** activity was also found in the North Basin (site 27S, 100 µg p-np/g*hr). The slowest activity, that is, the least amount of $\rho$-nitrophenol released was observed in the South basin (site 60B, 114 µg p-np/g*hr).

The activity difference between the South and North basins was determined to be statistically higher in the North basin than the South basin for both acid and alkaline phosphatase activity (Leduc & Adkins 2005). (Single-tail t-test, $\alpha$ = 0.05)




**Content of $\rho$-nitrophenyl phosphate released by hydrolysis of $\rho$-nitrophenyl phosphate by acid (pH 6.5) and alkaline (pH 11) phosphatase**

With both acid and alkaline phosphatase activities being highest in the North basin where most of the profuse algal blooms occur, it is possible that microbial phosphatase activity potentially contributes toward these algal blooms by the release of inorganic phosphorus into the lake water.

An interesting feature of microbial phosphatases, especially alkaline phosphatase, is that they are not released in the presence of excess dissolved phosphate (Jones 2002). This may explain the lower phosphatase activity in sediments of the South basin, which receives approximately 5,100 tonnes of phosphorus-containing effluent (approximately 77% of the total phosphorus load of Lake Winnipeg) annually by way of the Red and Winnipeg Rivers (LWSB 2005).

As the water flows northward, dissolved nutrients become diluted and phosphorus levels decrease allowing phosphatase activity to resume.

It is important to note that activity at each site contributes to the total phosphorus being introduced into the lake. Phosphorus that is released by microbial activity from every site across the lake in the South and North basins throughout the year may thus contribute to the total phosphorus introduced into the water.

Although most of the inorganic phosphorus in the lake originates from anthropogenic sources, **the results of this study indicate that microbial decomposition of organic matter in the sediment released a significant amount of inorganic phosphorus into the lake** as well. This microbial source may contribute to increased primary production and eutrophication in the North basin and should not be overlooked.

## FUTURE RESEARCH

Examination of phosphatase activity of sediments from all of the 65 Lake Winnipeg study sites needs to be undertaken in order to grasp the full scope of phosphorus inputs through the activity of the heterotrophic microbial community in these sediments.