Potential Effects of Phosphorus on Lake Water Quality

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ABSTRACT

Pollution resulting from increased human activities is threating lakes. Its effects have been characterized by serious eutrophication. A steady increase of phosphorus loading is most important factor of lake eutrophication. Phosphorus enters in fresh water system as atmospheric input point sources, nonpoint sources and sources within water system. Generally the 10% sources of phosphorus come from point sources such as wastewater and industrial discharge and left come from the nonpoint sources.

Phosphorus is the nutrient essential for the plant growth. Too much phosphorus in water is the cause of algal bloom and excessive plant growth affecting the lake water quality in different ways. Phosphorus provokes complex reaction in the lakes. Phosphorus often includes both soluble reactive phosphorus and total phosphorus. Soluble reactive phosphorus dissolves in water and readily aids to the plant growth. Total phosphorus is considered a bitter indicator for a lake nutrient. Elevated concentration of phosphorus level however can increases the productivity of fresh water system and in very productive fresh water there is less availability of oxygen which then affects the fish life in lakes.

Various management practices and various control measures can improve water quality of lakes. This paper highlights sources, impacts and control measures of phosphorus in the lake water.

INTRODUCTION

Pollution resulting from increased human activities and through surface run off is affecting the lake water quality. Over enrichment of water by nutrients principally nitrate and phosphates is known as eutrophication [9]. Eutrophication results in excessive plant and algal growth. A steady increase of phosphorus loading is most important factor of lake eutrophicatrion [8].

Many fresh water sources have become eutrophied and polluted by runoff from agriculture and industry as well as discharge of waste water in to them. External inputs of nutrient-rich (N, P) and polluted water are main cause of lake eutrophication [9]. Of these many problems are closely related to the concentration phosphorus [5]. It is one

of the important mineral nutrients for biological, aquatic as well as environmental system. Phosphorus occurs naturally and it is commonly found in fertilizers, manure, detergents, municipal and industrial waste [17].

Phosphorus exists naturally in the rocks. An important source of phosphorus in environment is phosphate rocks [3]. Phosphorus is the 11thmost abundant mineral in earth's crust [6]. Phosphorus has chemical symbol 'P'. It comes in group VA in periodic table of elements. It has atomic number 15, atomic weight 30.97376 [6]. It is the multivalent non-metal of the nitrogen group. The variable oxidation states of phosphorus are +5, +3 but most preferable oxidation state is +5 [11].

In most of the lakes and rivers phosphorus is the limiting nutrient for the growth of algae [19]. It also causes various complex reactions in the lake. Elevated concentration of phosphorus levels can increases the productivity of fresh water system, due to this there is less availability of the oxygen which then affects the aquatic life of the lakes [7].

CLASSIFICATION OF LAKES

Increasing the amount of nutrients entering a stream or lake will increase the growth of aquatic plants and other organisms. Although these nutrients are necessary, excessive levels over stimulate the lake or stream, reducing the quality of the water.

Table 1 : Trophic status of fresh water based on phosphorus concentration and the distribution

Trophic status	Definition, characteristics
Oligotrophic	Clean lakes, excellent water quality, low pollution, little wildlife
Mesotrophic	Moderate algal growth, more nutrient to support a more varied wildlife
Eutrophic	High nutrient content. Potential water treatment problems with taste and odour. Three categories of eutrophic are moderate, strong, and high.
Hypereutrophic	Highly productive, murky waters. Can support cyanobacteria that may produce toxins.

The progressive deterioration of water quality from over stimulation by nutrients is called eutrophication [4, 10].

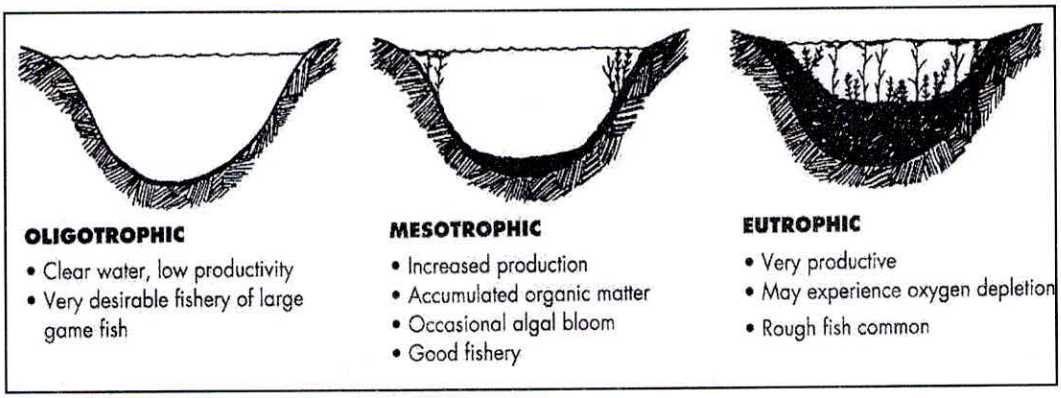

Fig. 1: Trophic Status of Lakes

(source-www.dnr.state.wi.us/.../lakes/trophics.htm)

SOURCES OF PHOSPHORUS

The most important natural source of phosphorus to lakes is from igneous rocks containing the mineral apatite $(Ca_5 (PO_4)^{3+}$. Under normal weather conditions rocks release phosphorus. In nature it occurs as the phosphate ion, consisting of a phosphorus atom and some number of oxygen atoms. The most abundant form is orthophosphate,

The principal sources of phosphate are losses from agricultural activities, forestry atmospheric and municipal and industrial waste water. These sources can be classified as

1) Inputs , including rain and dust
2) Point sources clearly have defined entry point such as sewage treatment plants and industrial effluents
3) Nonpoint sources, which does not have a discrete discharge point including stream water, agricultural and land clearing runoff and
4) Nonpoint sources from riverbanks, from within the water system, including wash out from sediments.

Point sources are relatively simple to monitor and regulate often these can be controlled. Nonpoint sources are difficult to measure and regulate. The rate at which phosphorus loads enter freshwater system varies with the geology, land use, human activities and pollution [7, 13].

Example of point and nonpoint sources are

Phosphorus can enter surface water from both point sources and non-point sources [17].

Examples of Point Sources:	***Examples of Non-Point Sources:***
• municipal wastewater systems • industrial discharges • feedlots and manure piles • residential septic systems  Controllable point source discharge from a municipal lagoon.	• erosion of soil from agricultural land, natural habitat and stream banks • runoff water from agricultural land, natural habitat and golf courses • wildlife access to surface water • Allowing livestock to graze along lakes and streams. The practice of allowing livestock uncontrolled access to surface water should be avoided.

FORMS OF PHOSPHORUS

In freshwater system, phosphorus occurs generally as inorganic phosphorus, particles of organic phosphorus and dissolved organic phosphorus. Aquatic algae and plant use an inorganic form of phosphorus for their nutrition. Phosphorus in natural water is divided into three component parts: soluble reactive phosphorus (SRP), soluble uncreative or soluble organic phosphorus (SUP) and particulate phosphorus (PP) .The sum of SRP and SUP is called soluble phosphorus (SP), and the sum of all phosphorus components is termed total phosphorus (TP). Soluble reactive phosphors dissolve in water and readily aids to the plant growth. Total phosphorus is considered a bitter indicator for lake nutrient. SUP are the organic forms of phosphorus and chains of on organic phosphorus molecules termed as polyphosphate. SP contain all filterable forms of phosphorus both organic and inorganic which are converted to orthophosphate after digestion. Total phosphorus incorporates the total of all particulate phosphorus form .It largely defined on the basis of phosphorus that oxidized to orthophosphate by specific oxidant [18, 7, 20].

PHOSPHORUS IN THE ENVIRONMENT

Phosphorus normally occurs in nature as part of a phosphate ion, consisting of a phosphorus atom and some number of oxygen atoms, the most abundant form (called orthophosphate) having four oxygen. PO_4^{3-}. Most phosphates are found as salts in ocean sediments or in rocks. Over time, geologic processes can bring ocean sediments to land, and weathering will carry terrestrial phosphates back to the ocean. Plants absorb phosphates from the soil. The plants may then be consumed by herbivores that in turn may be consumed by carnivores. After death, the animal or plant decays, and the phosphates are returned to the soil. Runoff may carry them back to the ocean or they may be reincorporated into rock [14]. In most of the lakes

and rivers, phosphorus is primary limiting nutrient that limits the growth of algae and plants. In some systems, the nutrient form of phosphorus is taken up quickly and so difficult to measure accurately [12].

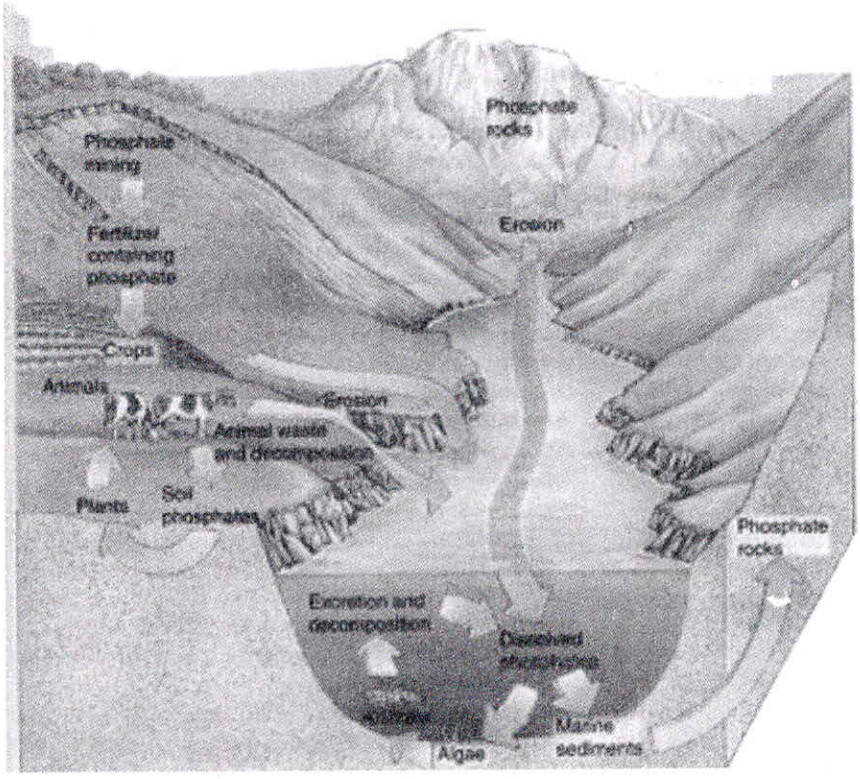

Fig. 2: Phosphorus in Environment

(Source: vincejtremate.tripod.com/cycle/phosphorus.htm)

PHOSPHORUS CYCLE IN LAKE

Phosphorus cycle is the biogeochemical cycle that describes the movement of phosphorus through the lithosphere, hydrosphere and biosphere. In ecology the biogeochemical is a circuit where nutrients move back and forth between biotic and abiotic component of eco system [12]. Phosphorus moves in cycle through the environment changing its forms. Erosion caused by rainfall and runoff of streams removes phosphate from the phosphate rocks. The total phosphorus discharged by the streams is separated into dissolved phosphorus which remain in the water column and the phosphorus in particulate matter which settles to the bottom under the relatively quiescent conditions of the lake. The part of the soluble phosphorus which is accessible to the biota of the lake may be utilized by various organisms and their predators. Aquatic plants take in dissolved inorganic phosphorus and it becomes the part of their

body as organic phosphorus. Most of this utilized phosphorus eventually settles to the bottom of lake as organisms die some phosphorus is recycled from the sediments but on the balance is believe that there is net loss of phosphorus from the water column to the lake bottom. As the plants and animals produce waste or die the organic phosphorus they contain sinks to the bottom. Bacteria take over the decomposition process and convert it back to inorganic phosphorus. This inorganic phosphorus gets back in to the cycle when bottom is stirred up and it taken up by plants again. The natural phosphate cycle is badly affected by pollution, mainly from agricultural run-off containing phosphorus from sewage , phosphate derived from excreta and detergents. Phosphate pollution of lakes causes the algal blooms which reduced the dissolved oxygen in water disrupts the natural food chain [7, 19, 22, 15].

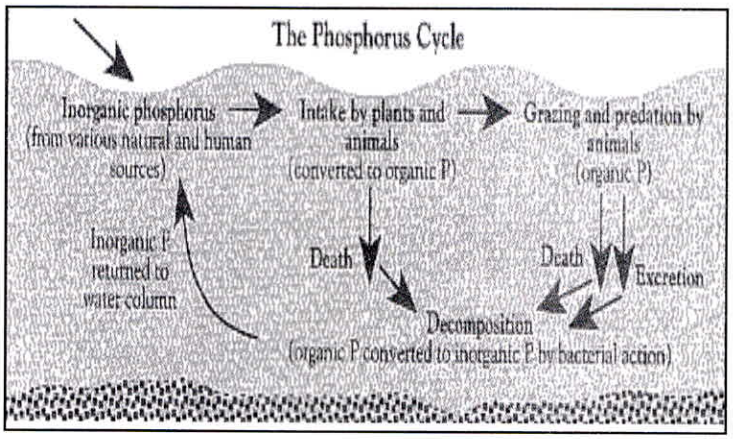

Fig. 3 (a): Phosphorus Cycle in Lake

(source: www.anr.state.vt.us/.../image/epa_phoscycle.gif)

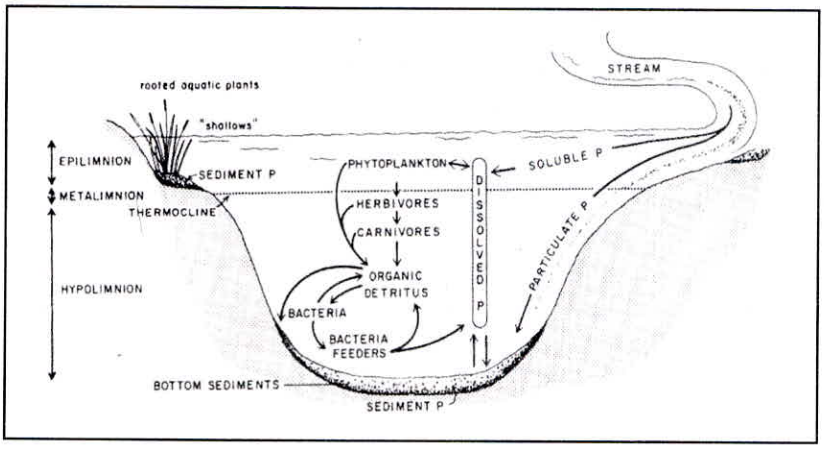

Fig. 3 (b): Phosphorus Cycle in Lake [19]

IMPACTS ON ENVIRONMENT

1) Phosphorus can quickly become a problem when present in high levels. Such increase in nutrients causes eutrophication, due to eutrophication both plant and algal growth increases to a harmful level of aquatic life.
2) Increase in animal growth and plant size, increases turbidity.
3) More organic matter falling to the bottom of the system in the form of plants and animals resulting in loss of oxygen in water , due to no oxygen at the bottom of lakes phosphorus that previously had been locked in sediments can release back in water causing internal loading of phosphorus which then creates the problem of high productivity.
4) Less oxygen can also affect the aquatic life of the lakes.
5) A type of algae called cyanobacteria grows in high concentration phosphorus. Cyanobacterial blooms can cause water quality problems. Some cyanobacteria also produce toxins that kill livestock and wildlife.
6) Growth of aquatic plants interfere with swimming and boating activities carried by human beings
7) Algal bloom have been linked to health problems ranging from skin irritation to liver damage to death, depending on type and duration of exposure
8) The livelihood of many fish, shellfish, and livestock has also been endangered through contact with this toxin. In addition to causing animal and human health concerns large amounts of blue-green algae can literally suffocate organisms by depleting water of life-sustaining oxygen by causing hypoxic or anoxic conditions [3, 17].

PHOSPHORUS REMOVAL TECHNIQUES

The increased load of phosphorus in environment as a result of human activities has been matter of concern .Human contribution to results primarily from the use of phosphorus containing detergents. There are various removal techniques for the phosphorus generally they are classified chemical and biological methods. Biological methods involving bacteria formed in activated sludge they have high tendency to absorb the phosphorus. They are very efficient in removing the phosphorus from the water system.

The more popular method of phosphorus removal is chemical. A compound is selected that will react with phosphate in polluted water, forming an insoluble product that can then be filtered off. The two most common substances used for this process are alum, aluminum sulfate and lime, or calcium hydroxide. An alum treatment works in two different ways. Some aluminum sulfate reacts directly with phosphate in the wastewater to form insoluble aluminum phosphate. At the same time, the aluminium ion hydrolyzes in water to form a thick, gelatinous precipitate of aluminium hydroxide that carries phosphate with it as it settles out of solution.

The addition of lime to wastewater results in the formation of another insoluble product, calcium hydroxyapatite, which also settles out of solution.

By determining the concentration of phosphorus in wastewater, these chemical treatments can be used very precisely. Exactly enough alum or lime can be added to precipitate out the phosphate in the water. Such treatments are normally effective in removing about 95% of all phosphorus originally present in a sample of wastewater [16].

Other methods includes- diversion, phsophorus precipitation, dilution or flushing, water flow management, biomanipulation [2].

MANAGEMENT STRATEGIES FOR CONTROLLING PHOSPHORUS

The program of lake management is to protect and restore the ecological integrity and recreational value of lakes. Its objectives are to achieve and maintain high water quality and natural habitat conditions through pollution prevention, pollution source abatement, and implementation of lake restoration technologies. Components of lake management are baseline monitoring, diagnostic study, management plan, implementation, public education and technical resistance etc [10,2].

CONCLUSION

Phosphorus is a critical element for crop production and also for environment. Up to a certain level phosphorus is essential for aquatic life but increase in the level can also increases the algal blooms which then affects the lake water quality by different means. Proper management can limit the amounts of phosphorus reaching streams, wetlands and lakes [1,10].

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