NUTRIENTS AND BIOLOGICAL PRODUCTION IN LAKES

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INTRODUCTION

The primary production of thee phytoplankton is one of the most important sources of the energy input in fresh waters (Moss 1980).

It is regulated in space and time by environmental factors, such as light temperature, pH, nutrients, external loading weather conditions and biological interactions. The rate of primary production is usually limited by the amount of inorganic nutrients and available radiant energy. However, various conditions can occur in nature which decrease rate of primary production even though substantial amount of light and nutrients are present (Smith *et al*, 1982).

The limitation of aquatic productivity by inorganic nutrients other than CO_2 is the normal situation in unpolluted aquatic escosystems both fresh water (Lund 1965, 1971) and marine (Strickland, 1965).

Inorganic phosphate is the nutrient most frequently found to control aquatic production prior to the on set of eutrophication of inland waters and it seems that nitrogen limitation is more typical of polluted standing waters.

Eutrophic conditions in lakes are caused by external nutrient loading from agriculture and other human activities. Eutrophication can also be the consequence of increased retention times and storage of nutrient rich run off water in rainy season. Besides agricultural inputs, atmospheric deposition can not be neglected in many areas as a real, sometimes significant contribution to the nutrient loading of lakes and coastal sees (Jenkinson, 1990).

Recognition of the chemical nutrients limiting biological production in lakes has been the basis of enlightened recommendation and management decisions.

This paper is a review of studies on effects of nutrients on biological productivity and efforts made so far at restoration of nutrients in lakes. It is to provide an understanding of the basic scientific process occuring in lakes, therefore of prime importance in maintaining water quality standards for propagation of effective lake management.

Nutrient Cycling in Lakes

In the literature many schemes of the phosphorus and nitrogen cycles in aquatic systems have been presented. The net fluxes of N and P available for primary production are of key interest when from a management point of view the response towards reduced loading of N or P has to be considered (Lyklema,1993).

Nitrogen

The dominant loss term in lakes is denitrification. The necessary anoxic conditions are found in the sediments generally at a depth of a few mm high denitrification rates will be found when appropriate election donors are present, which is normally the case in lakes with some productivity and at high nitrate concentrations.

The ammonification of detritus settling into the sediments creates a suitable environment for nitrification as long as sufficient oxygen is available in the top layer of the sediments and the temperature is not too low.

The role of ammonium in nitrogen cycle has been highlightened by Wynne (1991) on lake kinneret, (the Biblical sea of Galilee) the only natural fresh water lake in Israel. Ammonium (NH_4) is the only inorganic nitrogen form to be directly taken up and metabolized by phytoplankton uptake of nitrate (NO_3) also occurs but to be reduced to NH_4 before N-NO_3 can be utilized by cell. Reduction of initrate is a two stage process involving the enzymes nitrate reductase (NR) which catalyses the reduction of nitrate to nitrite and nitrite reductase (N,R) which catalyses the reduction of NO_2 to NH_4. Both uptake of NO_3 and enzyme synthesis are inhibited by the presence of ammonium. It has been observed in many lakes and seas that nitrification occurs predominantly in the sediments. However, nitrification will become supressed at high organic loading. Of the sediments and high temperature due to limited oxygen penetration. Deritrification, is stimulated by anoxic conditions and steep redox gradients. Macrophyte coverage may also stimulate deritrification losses by transporting oxygen into the root zone and thereby stimulating nitrification. In a review Seitzinger (1990) presents data indicating that in fresh water sediments the percentage of the efflux of nitrogen from the sediments that is N_2 is higher than in marine sediments.

Phosphorus

Both P and N are to some extent best from water bodies by burial of more or less refracture organic matter. Phosphate is fixed conservatively within the water body in the sediments by absorption and formation of insoluble compounds. In fresh waters except very hard water systems, iron oxides control this fixation but the role of aluminium probably has been overlooked in many studies (Portielje, 1993).

For the long term it should be stressed that the fraction of the phosphate input that can be immobilized in the sediments is dependent on the flux of absorbing material, for iron with a rate high partition coeffiicient for the equilibrium with lake water particles of various origin the removal by coagulation and settling is very efficient except for lakes with short detention times (O'Melia, 1985). This means that most of thee input of iron to a lake will accumulate in the sediments.

According to Wisnewski (1991) three factors are considered to control the exchange of phosphorus between sediments and water. Traditionally it was understood that this exchange was controlled mainly by objective factors such as the chemical composition of sediments and the overlying water, redox potential and pH.

Recent microbiological studies have shown that the release and fixation of phosphorus in sediments may be controlled by production and decomposition of microbial biomass. as well as by redox - dependent changes in the physiology of bacteria living in the superfacial layer of the sediments Benthic invertebrates also affect phosphrous exchange through decomposition and excretion, through increasing phosphorus mobility in the sediment and by accelerating phosphorus flux from sediment to the overlying water . (Wisniewzki,1991).

Limiting Nutrient N or P

At any time during the growing season disregarding temporary effects of luxury uptake etc, the ratio of potential N and P concentrations available for algae fluxes and input upon which it is based will define which nutrient may control the maximum biomass. At high levels this control will not be exerted by the nutrients but by lights. Lindholm and Erikson (1990) observed that besides light nitrogen rather than phosphorus availability limited primary productivity of Lake Markusbolefjarden.

In another view Herod and Lotvanovics (1985) observed that phytoplankton is limited by phosphorus or phosphorus and nitrogen and sometimes by light due to self shading.

Naiewakjco and voltalina (1986) sugested phosphorus is the specific nutrient that limites phtosynthesis and phytoplankton biomass during thermal stratiification.

Fahmenstriel *et al* (1990) observed that although a combination of physical, chemical and biological factors control the rate of photosynthesis and plankton biomass in the lakes, they believe that chemical factors partcularly phosphrous are dominant in most cases and should remain the focus of controlling phytoplankton biomass in Great lakes.

Restoration

Many lakes and reservoirs receive nutrients from sources that do not submit to cost-effective control for the restoration of such bodies of water, alternatives to reductions in external nutrient laoding include efforts to affect the course of community development as well as treatments to reduce internal nutrient loading and phytoplankton biomass, Klemers and Barke (1991). the former include measure s such as mixting that may involve chnages in internal loading as well as manipulations of consumer populations (fish, zooplankton) to effect changes at the producer level (Shapiro, 1980).

For example, Klemer and Barke (1991) desgined and tested the effectiveness of silica enrichment and artificial mixing as means of regulating phytoplankton on Eutropic Eav Galle reservoir. They made the following suggestions:

(a) that neither mixing above or mixing with sillica enrichment was likely to deter dominance of nuisance phytoplanton in the reservoir
(b) that subsequence alum treatment provided only a single simmer of relief from blooms of nuisance algae
(c) that liming may be preferable to alum treatments (Babin *et al* 1989)
(d) The best alternative to expensive dredging operations may be a more biological manipulation involving a restrituring of fish and zooplankton components of the aquative community in an effort to reduce algal biomass. (Shapire, 1980).

Deklet *et al* (1990) reported restoration of the Loosdrecht lakes which became highly eutrophic due to the inlet of polluted water from the river Vecht. The direction of internal P loading was achieved by replacing the water supply from the river with dephosphorized water from the Amsterdam-Rhine cnal Vanliere (1986).

Klein and Chorus (1991) reported restoration of lake schiachtensce by treatment of its mamn inflow phisphate precipitation, chiefly with Feclz and subsequent filtration), and by withdrawal of hypolimnective water during late summer. Chris (1990) observed that Lake Tvvsvlanjaru' in Finland was restored after eutrophication by mechanical aeration of hypolimnion during stratification and diversion of all the point source loading away from the lake.

Karlman (1973) observed the low level of nutrients in Kainji lake and recommended the introduction of plant nutrients through intensified use of fertilizers in the drainage area which may cause a high level of primary production.

In conclusion, systematic water quality monitoring of lakes should be regular. The programme should focuss on primary production evaluation. The methodology could differ from time to time and appropriate restoration measures could be applied.

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