EUTROPHICATION - CAUSES AND CONTROL

by

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INTRODUCTION

In recent years, increasing concern has been expressed regarding nutrients in surface waters. This concern, by both the water resource management people and the general public, has been due mainly to the increasing problem of eutrophication of surface waters throughout the United States.

Eutrophication has been defined as the process of enrichment with nutrients. This is to say that the aquatic life in a body of water become so fertilized with the nutrient content of its water that productivity commences at a much faster rate than their decay. The result is the frequent appearance of algal blooms on the surface of lakes and reservoirs. Algal blooms have caused nuisance, aroused public indignation, and increased the cost of water treatment. It is the purpose of this paper to present a review of the current knowledge on eutrophication, its effects on water quality and an appraisal of its causes and control.

CAUSES OF EUTROPHICATION

As previously stated, eutrophication has been defined as the process of enrichment with nutrients. Fruh (1) defined the common nutrients essential for plant growth as carbon, hydrogen, oxygen, sulfur, calcium, magnesium, nitrogen and phosphorus. Among these nutrients, only nitrogen and phosphorus have received the major attention and been recognized as the controlling stimulants of eutrophication. This is probably due to the fact that only trace amounts of nitrogen and phosphorus have been found to trigger algal blooms. Sawyer et.al. (2) reported from a study of Wisconsin lakes that only 0.30 mg/1 of inorganic nitrogen and 0.015 mg/1 of soluble phosphorus produced nuisance algal blooms. Maloney (3) of U. S. Public Health Service attempted to determine the minimum concentrations of nutrients necessary to support the growth of algae. His tentative conclusion was that nitrogen should be below 0.1 mg/1 and phosphorus below 0.01 mg/1 with essentially no iron present, if nutrients scarcity is to prevent algal growth.

There seems to be a controversy among investigators on whether nitrogen or phosphorus is considered to be the controlling biostimulant and causing algal blooms. Recently and due to the ability of some blue-green algae to fix nitrogen from the atmosphere in the presence of phosphorus, it has been generally conceded that phosphorus is the main limiting stimulant. On the other hand it has been found (4) that algae can store phosphate when excess quantities are available and several investigators claim nitrogen is the limiting nutrient.

SOURCES OF NUTRIENTS

The basic contributors of nutrients to lakes and reservoirs include agricultural and urban run-off, industrial and municipal discharges, precipitation from the atmosphere, and the interchange of bottom deposits.

In a study of nutrient sources entering Yakima River, Washington, Sylvester and Seabloom (5) considered that irrigation return flow as the major contributor of nutrients when compared with industrial and domestic effluents. Englbrecht and Morgan (6) regarded the drainage from land as a significant source of phosphate to the Kaskaskia River in Illinois. Sylvester (7) reported that nitrates were twice as high and the nitrogen to phosphorus ratio average 2 1/2 times in the sub-surface drains to that in the surface drains carrying irrigation return flows. It appears that a significant portion of the increased amounts of fertilizers applied to the land are carried off in the drainage run-off.

An important fraction of the nutrients in a lake may be derived from the sediments accumulated at the bottom. This is particularly true in shallow waters where, with the action of wind, the sediments are more easily stirred. The fall and spring turnovers in a thermally stratified lake may also contribute to the stirring of the bottom sediments. Sawyer (8) reviewed some of the Madison study and suggested the CO_2 feed back from bottom deposits and the role of bacteria must be closely considered when studying nutrients and their sources.

Contribution of nutrients by atmospheric precipitation have received the least consideration of other sources. Several investigators have attempted to report the amount of inorganic nitrogen contributed by rainfall; however, the data on phosphorus in rainfall is meager.

Without any doubt, the major contributor of nutrients to surface waters is the discharges of treated municipal and industrial waste effluents. The entire concept upon which treatment of domestic wastes has been based is the matter of BOD reduction rather than nutrients removal. Consequently, sewage treatment processes have become more sophisticated only in their ability to oxidize organic material. Unfortunately, the oxidized forms of nitrogen and phosphorus are in themselves significant stimulants.

The amount of nutrients contributed by sewage effluents have been reported by several investigators. Sawyer et al. (9) during their study on the algal nuisance in the lower Madison lakes reported that 76% of the total nitrogen and 88% of the soluble phosphorus entering Lake Waubesa was contributed by effluent from the sewage treatment plant. Fitzgerald and Rohlick (10) reported nitrogen concentrations of 20-50 mg/l and soluble phosphorus concentrations of 1-13 mg/l in secondary treatment plant effluents. In a study of the content of sewage from 12 separate sources, Rudolfs (11) concluded that the annual per capita contribution of phosphorus ranged from 0.6 - 1.5 pounds. The secondary treatment plant effluent of the combined sewage and industrial wastes of Madison, Wisconsin, has annual per capita contribution of 8.5 pounds of inorganic nitrogen and 2.8 - 3.7 pounds of soluble phosphorus (12). Similar studies of oxidation pond effluents in Wisconsin indicated annual per capita contributions of 4.1 pounds inorganic nitrogen and 1.1 pounds of soluble phosphorous (13). It must be emphasized that a continued high rate of nutrient supply does not appear to be necessary for continued algal production. After an initial stimulus, the recycling of nutrients within the lake basin is sufficient to promote algal blooms for at least a number of years. The initial stimulus is most often supplied by dissolved phosphorus.

EFFECTS OF EUTROPHICATION

Unfortunately, with the exception of special fish ponds where increased nutrients are desirable, the effects of eutrophication are generally undesirable. Tastes and odors associated with algal death and decomposition are probably the most frequent and undesirable characteristics of eutrophic waters. Removal of taste and odor by physical and chemical processes is expensive and elevates the cost of water treatment. Increased color and turbidity and the frequent clogging of sand filters are other factors which add to the extra cost of treating eutrophic waters. The discoloration of water and the visible floating mats of algae and macrophytic vegetation destroy the aesthatic values of lakes and reservoirs. Fishing may be impaired; and bathing, boating, and other water sports may be prohibited or become highly undesirable thus destroying or reducing the recreational value of the water facility. Development of anaerobic zones in lakes and streams, toxic algae, and lowering of property values are more reasons why eutrophication is highly undesirable.

CONTROL OF EUTROPHICATION

Since eutrophication is the product of enrichment with nutrients, it is obvious that control measures should be based on either removal, reduction or prevention of the addition of nutrients. Presently, the most popular control measure is the diversion of nutrient rich effluents from the receiving body of water. Large diversion ditches have been built to implement the disposal of waste (1, 14, 15). However, this method simply places the problem elsewhere instead of removing the nutrients from the effluent.

In cases where waste water diversion is not economically feasible, tertiary treatment of wastes is being used. An extensive research program is underway by universities and government agencies throughout the U. S. for the development of physical, chemical and biological treatment processes that will make nutrient removal economically feasible. The description of these processes is beyond the scope of this paper.

Zoning of residential, industrial, recreational, or natural areas has been recommended where agricultural and/or urban drainage are the primary sources of nutrients. Other means to overcome the problem of eutrophication have been suggested but do not seem of practical importance. These include harvesting of weeds and algae, roughfish removal, dredging, low flow augmentation, and the application of chemicals.

DISCUSSION AND CONCLUSION

The problem of eutrophication of surface waters in the United States has been growing at an alarming rate. This is mainly due to the discharge of large volumes of treated sewage effluents rich in biostimulants, i.e., nitrogen and phosphorus into surface waters. The result is the consistent appearance of algal blooms in lakes and reservoirs.

Until recently, the removal of nutrients from waste effluent has not been considered as an objective of sewage treatment, nor has it been the goal of water quality regulation. However, as the problem of eutrophication is magnified and the great present and future demand for surface water supplies is recognized, the public agencies responsible for control of water quality have begun to set stream standards intended to exclude the discharge of growth stimulating substances into receiving waters. These requirements have caught the engineering profession without an established technology for an economic removal of nutrients.

Therefore, until a method is devised to economically and efficiently remove nutrients from sewage, the decision will be to either prevent the discharge of sewage or learn to live with the problem.

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