

EUTROPHICATION

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Introduction

Eutrophication describes a cascade of processes that occur in aquatic and terrestrial ecosystems in response to an increase in nutrient inputs. Phosphorus (P) and nitrogen (N) are the nutrients that drive most eutrophication processes. In aquatic environments eutrophication can lead to excessive algal growth, low levels of dissolved oxygen, the death of fish, increased turbidity, and a loss of species diversity. These conditions threaten the long-term sustainability of fisheries and recreational uses of surface waters. In terrestrial environments, excess nutrient inputs to soils in managed ecosystems (e.g., agriculture, urban horticulture) can increase the risk of nutrient losses to groundwaters and surface waters. This can then lead to eutrophication of surface waters and also to human health problems if drinking waters are too enriched in nitrate-N or contaminated by toxic by-products produced through chlorination of eutrophic waters. Overloading natural ecosystems (e.g., forests) with nutrients can lead to soil acidification and changes in the composition and diversity of native plant species, both of which are usually ecologically undesirable.

Because N and P are essential nutrients for the growth and well-being of plants and animals – and because they are relatively inexpensive – many human activities result in the discharge of N and P into some sector of the environment. Both nutrients are discharged from point sources such as municipal wastewater treatment plants and concentrated animal-feeding operations (CAFOs). Years of effort and billions of dollars have been invested in reducing point-source nutrient pollution of surface waters by improving the nutrient-removal efficiency of wastewater treatment plants. N and P are also common nonpoint pollutants that are widely added to soils as soil amendments for crop production (e.g., fertilizers, animal manures, and other by-products such as composts, and municipal wastewaters and biosolids) or via soil-based wastewater treatment systems such as septic systems. Combustion of fossil fuels generates biologically available N and contributes to atmospheric contamination of many watersheds. Soil characteristics (physical, chemical, and biological) and soil-management practices profoundly influence the potential for nonpoint-source pollution of water

bodies by nutrients and also determine the response of terrestrial biota to nutrient additions. Because of this, the implementation of ‘best management practices’ (BMPs) that reduce N and P losses from agricultural soils by processes such as erosion, runoff, and leaching, is a high priority worldwide today.

Aquatic Eutrophication

Causes

Additions of nutrients can generate remarkable changes in the primary productivity (the generation of biomass through photosynthesis) of aquatic systems. Because so many aspects of a freshwater ecosystem can be traced to nutrient supply, nutrient status is the basis for the widely used trophic (i.e., nutrition level) classification system applied to water bodies. Low-nutrient water bodies are classified as ‘oligotrophic’ (poorly nourished); high-nutrient water bodies are termed ‘eutrophic’ (highly nourished), and the intermediate state is referred to as ‘mesotrophic’ (Figure 1). Extremely nutrient-rich conditions do occur and these water bodies are classified as ‘hypereutrophic.’

Limiting Nutrients

The nutrient status of a water body is not constant. Decreases can occur due to control of point-source pollution discharges and widespread implementation of BMPs to curb nutrient inputs from nonpoint pollution sources. More often, the nutrient supply within an aquatic ecosystem increases over time. This increase is known as eutrophication – it can occur naturally in response to slow increases in the stores of organic matter and sediment within the system. If the rate of nutrient increase is accelerated due to human activities, the process is known as ‘anthropogenic eutrophication.’

In the nineteenth century, Justus von Liebig developed the ‘law of the minimum’ to indicate that growth of most organisms is controlled by the ‘limiting nutrient,’ the nutrient in least supply. At the beginning of the twentieth century, Brandt extended Liebig’s insights to surface water, noting that plankton (microscopic, free-floating plant and animal organisms that form the base of the food chain in aquatic environments) abundance was correlated with nutrient concentrations in freshwater lakes in Germany. Later, A.C. Redfield pointed out that the Liebig law should be viewed in the context of the relative ratios of nutrients found within living algae. Redfield found