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Review Article

Causes and effects of eutrophication on aquatic life

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ABSTRACT

The word 'eutrophic' comes from the Greek word eutrophos meaning well-fed. Human-induced pollution through the impacts of excessive fertilizer use, untreated wastewater effluents, and detergents significantly increases nutrient loading into lakes, accelerating eutrophication beyond natural levels and generating deleterious changes to the natural ecosystem The Eutrophication process has severe environmental impacts. Dead zones result from these impacts, which include algal blooms and hypoxia. Enhanced growth of aquatic vegetation or phytoplankton and algal blooms disrupts functioning of the ecosystem, causing a variety of problems such as lack of oxygen needed for fish and shellfish to survive. Control and management of eutrophication is a complex issue and will require the collective efforts of scientists, policy makers, and citizens to reduce nutrient inputs, to develop effective, long term bio-manipulation techniques, and to eventually restore aquatic communities.

KEYWORDS

Eutrophication | Algal blooms | Aquatic life

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Introduction

Eutrophication is characterized by excessive plant and algal growth due to the increased availability of one or more limiting growth factors needed for photosynthesis (Schindler 2006), such as sunlight, carbon dioxide, and nutrient fertilizers. Eutrophication occurs naturally over centuries as lakes age and are filled in with sediments (Carpenter 1981). Eutrophication is a process, both natural and anthropogenic of origin, which causes an increase in the supply of plant nutrients to natural waters and results in the growth of nuisance algae and higher aquatic plants. The term eutrophication has been defined invarious ways, ranging from "the natural aging of a water body to a eutrophic state, which occurs over very long (geological) time", to "the rapid rise in trophic status of a water body as a result of industrialization", which is sometimes termed "cultural eutrophication".

Eutrophication is a natural process whereby lakes, estuaries and slow-moving streams receive excess nutrients as a consequence of weathering of rocks and soils from the surrounding watershed. Increased nutrient inputs, particularly phosphorus and nitrogen, result in increased growth of aquatic plants and organic production of the water body. Young water bodies (lakes and man made reservoirs) usually are oligotrophic as they have low levels of nutrients and correspondingly low levels of biological activity. In contrast, old water bodies possess high biological activity as a consequence of high nutrient levels. These are referred to as eutrophic water bodies. The natural time scale from being oligotrophic to eutrophic is in the order of thousands of years, depending on the levels of encrusted minerals and on the rate of watershed weathering, among other environmental characteristics (Wetzel, 1975). These terms were first applied to lakes by Naumann in early 1900 (Naumann, 1919, 1927) noting that oligotrophic lakes contained modest levels of algae and were often found in igneous rock areas while eutrophic lakes contained high amounts of algae and were found in more fertile lowland regions. The author concluded that within a normal thermal range, levels of phosphorus, nitrogen and calcium are the primary determining factors of lake trophic status.

Causes of Eutrophication

The functioning of aquatic ecosystems is governed by dynamic balances. Eutrophication is an imbalance in functioning, triggered by a change in the quantity, relative proportions or chemical forms of nitrogen and phosphorus entering aquatic systems. The nature and intensity of responses also depends on environmental factors: long water residence times, high temperatures and a sufficient amount of light all stimulate eutrophication. Both continental and marine water ecosystems share the same general response mechanism to changes in nutrient flows (Claussen *et al*., 2009): an increase in nutrient inputs causes an increase in plant biomass, gradually generating a decrease in light penetration in the water column. Aquatic ecosystems thus shift from a system with limited nutrient inputs to a system gradually saturated in nutrients, in which light becomes the new limiting factor.

Increasing global population growth and the development of urban concentration, agricultural industrialization and specialization of agriculture per region, including crop-livestock decoupling by means of animal feed transport, phosphorus mining and chemical manufacturing process of mineral nitrogen (Haber-Bosch method) have led to an increase in loads and concentrations of nutrients in terrestrial environment, and ultimately in aquatic ecosystems (Smith and Schindler, 2009). Estimation of changes in loads varies from one publication to another based on the approach, the scale and the databases used (Moatarand Meybeck, 2005). Many historical analyses have been performed (Howarth, 2008; Chen *et al*., 2016; Lu and Tian, 2017; Minaudo *et al*., 2015; Floury *et al*., 2017). Based on the latest models deployed globally, outflows to the sea doubled during the 20th century, from34 to 64 Tg N per annum for nitrogen and from5 to 9 Tg P per annum for phosphorus.

The contribution of agriculture to these outputs has increased from 20% to 50% for nitrogen, and from 35% to 55% for phosphorus (Beusen *et al*., 2016). In industrial countries, agricultural sources are now dominant, higher for nitrogen than for phosphorus (Dupas *et al*., 2015).

The cultural eutrophication process consists of a continuous increase in the contribution of nutrients, mainly nitrogen and phosphorus (organic load) until it exceeds the capacity of the water body (*i.e.* the capacity of a lake, river or sea to purify itself), triggering structural changes in the waters.

These structural changes mainly depend on 3 factors:

Use of fertilisers: Agricultural practices and the use of fertilisers in the soil contribute to the accumulation of nutrients. When these nutrients reach high concentration levels and the ground is no longer able to assimilate them, they are carried by rain into rivers and groundwater that flow into lakes or seas.

Discharge of waste water into water bodies: In various parts of the world, and particularly in developing countries, waste water is discharged directly into water bodies such as rivers, lakes and seas. The result of this is the release of a high quantity of nutrients which stimulates the disproportionate growth of algae. In industrialised countries, on the other hand, waste water can be illegally discharged directly into water bodies. When instead water is treated by means of water treatment plants before discharge into the environment, the treatments applied are not always such as to reduce the organic load, with the consequent accumulation of nutrients in the ecosystem.

Reduction of self purification capacity: Over the years, lakes accumulate large quantities of solid material transported by the water (sediments). These sediments are such as to able to absorb large amounts of nutrients and pollutants. Consequently, the accumulation of sediments starts to fill the basin and, increasing the interactions between water and sediment, the resuspension of nutrients present at the bottom of the basin is facilitated (Sechi, 1986). This phenomenon could in fact lead to a further deterioration of water quality,accentuating the processes connected with eutrophication (Tonolli, 2001).

Effects of Eutrophication

The Eutrophication process has severe environmental impacts. Dead zones result from these impacts, which include algal blooms and hypoxia. Enhanced growth of aquatic vegetation or phytoplankton and algal blooms disrupts functioning of the ecosystem, causing a variety of problems such as lack of oxygen needed for fish and shellfish to survive. The water becomes cloudy, typically coloured a shade of green, yellow brown or red. Eutrophication also decreases the value of rivers, lakes and aesthetic enjoyment. Algal bloom caused by high nutrient levels and favourable conditions. Blooms can result in deoxygenation of the water when large masses of algae die and decompose, leading to the death of aquatic plants and animals.

Phosphorous, nitrogen, and other nutrients increase the productivity or fertility of marine ecosystems. Organisms such as phytoplankton, algae, and seaweeds will grow quickly and excessively on the water's surface. This rapid development of algae and phytoplankton is called an algal bloom. Algal blooms can create dead zones beneath them. Algal blooms prevent light from penetrating the water's surface. They also prevent oxygen from being absorbed by organisms beneath them. Sunlight is necessary for plants and organisms like phytoplankton and algae, which manufacture their own nutrients from sunlight, water, and carbon dioxide. The Eutrophication process has severe environmental impacts. Dead zones result from these impacts, which include algal blooms and hypoxia. Enhanced growth of aquatic vegetation or phytoplankton and algal blooms disrupts functioning of the ecosystem, causing a variety of problems such as lack of oxygen needed for fish and shellfish to survive.

Oxygen is necessary for almost all aquatic life, from sea grasses to fish. By depriving organisms of sunlight and oxygen, algal blooms negatively impact a variety of species that live below the water's surface. The number and diversity of bottom dwelling species are especially reduced. Because an alga dominates the aquatic ecosystem, algal blooms are sometimes referred to as "red tides" or "brown tides," depending on the color of the algae. Red tides actually have nothing to do with tides. They also have nothing to do with algae. The organism that causes red tides is a bacteria, called cyanobacteria. Algal blooms also cause larger-scale problems, such as human illness. Shellfish, such as oysters, are filter feeders. As they filter water, they absorb microbes associated with algal blooms.

Many of these microbes are toxic to people. People may become sick or even die from shellfish poisoning. Algal blooms can also lead to the death of marine mammals and shore birds that rely on the marine ecosystem for food. Wading birds, such as herons, and mammals, such as sea lions, depend on fish for survival. With fewer fish beneath algal blooms, these animals lose an important food source. Algal blooms can also impact aquaculture, or the farming of marine life.

Algal blooms usually die soon after they appear. The ecosystem simply cannot support the huge number of cyanobacteria. The organisms compete with one another for the remaining oxygen and nutrients. Algal blooms upset the delicate natural balance of plant and animal ecosystems in a waterway or wetland. Weed that washes ashore and forms rotting piles on beaches can cause offensive smells and become a health problem for nearby residents as well as a nuisance to beach users and fishers. An overabundance of algae can choke a body of water such as a river, clog irrigation pipes, and block out the light other plants, such as seagrasses, need to producefood. Excessive weed growth can eventually kill seagrass beds. When an algal bloom dies the process of decay can use up all the available oxygen in the water, effectively suffocating other aquatic life. This can kill fish, crabs and other animals, especially those that are attached or sedentary (do not move around). Some species of algae produce toxins.

Hypoxia occurs when algae and other organisms die from lack of oxygen and available nutrients. Hypoxia events often follow algal blooms. The cyanobacteria, algae, and phytoplankton sink to the seafloor, and are decomposed by bacteria. Even though oxygen can now flow freely through the aquatic ecosystem, the decomposition process uses up almost all of it. This lack of oxygen creates dead zones in which most aquatic species cannot survive. Eutrophication can cause serious effects to living resources or their habitats. Marine or estuarine systems with biogenically structured habitat, such as coral reefs or seagrass beds, are especially vulnerable to eutrophication. Bays, lagoons, enclosed seas, and open coastal waters can also be affected. The accelerated increase in the input of nutrients to the marine system represents a serious threat to the integrity of marine ecosystems and the resources they support.

Discussion

Water is not a commercial product like any other but rather a heritage which must be defended and protected, especially in the presence of a global decline in the availability of drinking water and increase in its demand.

Despite the considerable efforts made to improve the water quality by limiting nutrient enrichment, cultural eutrophicationand the resulting algal blooms continue to be the main cause of water pollution. The prevention and protection action thatcountries must adopt to safeguard the quality of surface water as requested not only by the scientific community another experts, but to an increasing extent also by citizens and environmental organizations, is therefore increasinglyimportant. Management of the eutrophic process is a complex issue that will require the collective efforts of scientists, policy makersand citizens.

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