Eutrophication

Definition

Eutrophication is a condition in an aquatic ecosystem where high nutrient concentrations stimulate blooms of algae (e.g., phytoplankton). Young lakes (and man -made reservoirs) usually have low levels of nutrients and correspondingly low levels of biological activity. Such lakes are referred to a being **oligotrophic**. Literally oligotrophic means little-nourished. Old lakes usually have high levels of nutrients and correspondingly high levels of biological activity. Such lakes are referred to as being **eutrophic**. Literally eutrophic means well-nourished.

Eutrophication can be defined also as :'The enrichment of waters, by inorganic plant nutrients, which results in the stimulation of an array of symptomatic changes. These include the increased production of algae and/or other aquatic plants, affecting the quality of the water and disturbing the balance of organisms present within it. Such changes may be undesirable and interfere with water uses'

All living things need specific nutrients to survive. When the aquatic system has too few nutrients, the water is **oligotrophic**. It makes sense that when there is not enough nutrition available for the variety of organisms living in an aquatic environment, serious problems will arise. However, when the aquatic system has an overabundance of nutrients, the water becomes **eutrophic.** A **eutrophic** stream, river or lake occurs when too many nutrients, like nitrogen and phosphorous, are present. Algae, plankton and other microorganisms love these types of nutrients, and when they are plentiful, these aquatic organisms can take over. When a lake, river or other aquatic system becomes eutrophic, it can have serious negative effects on other organisms like fish, birds and even people.

Eutrophication Classification

Lakes are often classified according to their trophy or degree of enrichment with nutrients and organic matter. They are classified by their trophic state with the main classes of oligotrophic, mesotrophic, eutrophic, and dystrophic.

Oligotrophic

Oligotrophic lakes are poorly supplied with plant nutrients and support little plant growth. As a result, biological productivity is generally low. The waters are clear, and the deepest layers are well supplied with oxygen throughout the year.

Mesotrophic

Mesotrophic lakes are intermediate in characteristics. They are moderately well supplied with plant nutrients and support moderate plant growth.

Eutrophic

Eutrophic lakes are richly supplied with plant nutrients and support heavy plant growths. As a result biological productivity is generally high. The waters are turbid because of dense growths of phytoplankton or they contain an abundance of rooted aquatic plants; deepest waters exhibit reduced concentrations of dissolved oxygen during periods of restricted circulation .

Dystrophic

In the dystrophic stage the water is highly polluted and no desirable species can be supported due to lack of oxygen and presence of toxins .

Algae are a natural component of aquatic environments, and even when they are abundant, it is not necessarily a problem. Often a proliferation of microscopic algae can have beneficial effects on fisheries and aquaculture industries such as oyster or mussel farms by increasing the amount of food available. Macroalgae provide sheltered habitat for juvenile fish. In fact, the local fishery production in the Peel-Harvey estuary almost doubled in the 1970s when weed (macroalgae) growth in the estuary was at its peak, without a similar increase in fishing effort. However, when algal blooms increase in intensity and frequency, the results can cause community concern, health problems, and in some cases can be catastrophic to the environment. The impacts are ecological, social and economic. Algal blooms upset the delicate natural balance of plant and animal ecosystems in a waterway or wetland. They can degrade recreation, conservation and scenic values, and interfere with economic uses such as fisheries and tourism. 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 over-abundance 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 produce food. 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.

If an algal bloom is so bad that it causes wide-spread death in the water, the organisms that die will all sink to the bottom and start to decompose. The microbes that break down these dead organisms use oxygen to do their work. So, in addition to the lack of oxygen from photosynthesis, there is also now a lack of oxygen from the decomposition of dead organisms.

When the oxygen in the water becomes too low, the water becomes hypoxic. If the hypoxia is bad enough, no organisms can survive there, and a dead zone is created. Dead zones are very dangerous because they not only have negative ecological impacts, but also cause economic issues. When aquatic animals die in large numbers, both commercial and recreational fishing industries are negatively impacted.

The most common nutrients causing eutrophication are nitrogen and phosphorus. The main source of nitrogen pollutants is run-off from agricultural land, whereas most phosphorus pollution comes from households and industry, including phosphorus-based detergents. These nutrients enter aquatic ecosystems via the air, surface water or groundwater. Most of the commercially fixed nitrogen and mined phosphorus goes into production of fertilizer. The rising demand for fertilizer has come from the need to meet the nutritional demands of our rapidly expanding human population. The rise in intensive fertilizer use has serious implications for coastal habitats because greater application results in greater runoff, and the fraction of fertilizer lost from fields will increase with intensity of application. Increased global production of nitrogenous fertilizers have largely been linked to concerns over the relationship between water quality and eutrophication. Nutrient removal in sewage treatment plants and promotion of phosphorus-free detergents are vital to minimize the impact of nitrogen and phosphorus pollution in Europe's waters.

The causes of eutrophication

The main causes of eutrophication are:

1- natural run-off of nutrients from the soil and the weathering of rocks
2- run-off of inorganic fertilizer (containing nitrates and phosphates)

3- run-off of manure from farms (containing nitrates, phosphates and ammonia)

4- run-off from erosion (following mining, construction work or poor land use)

5- discharge of detergents (containing phosphates)

6- discharge of partially treated or untreated sewage (containing nitrates and phosphates)

In most freshwater lakes the limiting nutrient is phosphorus, so an input of phosphorus in the form of phosphate ions (PO_4^{3-}) results in an increase in biological activity.

Some activities can lead to an increase in adverse eutrophication and, although they are very specific, they should be noted:

• **<u>Aquaculture development</u>:** Expansion of aquaculture contributes to eutrophication by the discharge of unused animal food and excreta of fish into the water;

• **<u>The transportation of exotic species</u>**: Mainly via the ballasts of big ships, toxic algae, cyanobacteria and nuisance weeds can be carried from endemic areas to uncontaminated ones. In these new environments they may find a favorable habitat for their diffusion and overgrowth, stimulated by nutrients availability;

• **<u>Reservoirs in arid lands</u>:** The construction of large reservoirs to store and manage water has been taking place all over the world. These dams are built in order to allow the collection of drainage waters through huge hydrographic basins. Erosion leads to the enrichment of the waters of these reservoirs by nutrients such as phosphorus

<u>The effects of eutrophication</u>

The main effects of eutrophication are an:

- increase in plant and animal biomass
- increase in growth of rooted plants, e.g. reeds
- increase in turbidity (cloudiness) of water
- increase in rate of sedimentation
- development of anoxic conditions (low oxygen levels)
- decrease in species diversity
- Change in dominant biota (e.g. carp replace trout and blue-green algae replace normal algae) and an increase in the frequency of algal blooms.

- Eutrophication itself affects the penetration of light through the water body because of the shadow effect coming from the development of algae and other living organisms and this reduces photosynthesis in deep water layers, and aquatic grass and weeds bottom development.

Some particular type of algae, which grow in highly nutrient enriched lakes and reservoirs (blue-green algae or cyanobacteria, and so-called dinoflagelates which produces red tide), release in the water very powerful toxins which are poisonous at very low concentrations.

Cyanotoxins can be classified into three groups:

1- **Hepatotoxins**.

These are the most frequently observed cyanotoxins. Experiments using mice indicate that they cause liver injury and can lead to death from liver haemorrhage and cardiac failure within a few hours of exposure at acute doses. Chronic exposure induces liver injury and promotes the growth of tumors.

2- **Neurotoxins.**

These are generally less common and act on the nervous system. In mice and aquatic birds, they cause rapid death by respiratory arrest, sometimes occurring in a few minutes.

3-**Dermatotoxins**.

These induce irritant and allergenic responses in tissues by simple contact.

High concentrations of nitrogen in the form of nitrate in water can also cause public health problems. They can inhibit the ability of infants to incorporate oxygen into their blood and so result in a condition called the blue baby syndrome or methemoglobinemia. For this to occur, nitrate levels must be above 10mg per liter in drinking water. The condition can be life-threatening.

Main consequences of eutrophication

Increase of biomass of phytoplankton and macrophyte vegetation

- Shift to bloom-forming algal species that might be toxic or inedible
- Increase of biomass of benthic and epiphytic algae
- Change in species composition of macrophyte vegetation
- Increase of biomass of consumer species

• Increase of incidence of fish kills
• Reduction in species diversity
• Reduction in harvestable fish biomass
• Decrease in water transparency
• Oxygen depletion in the water body
• Taste, odor, and drinking water treatment problems
• Decrease in perceived aesthetic value of the water body.

Eutrophication can have serious, long-term effects. The most notable effect of eutrophication is algal blooms. When a bloom occurs, the stream, river, lake or ocean becomes covered with algae, which is usually bright green. In addition to looking pretty ugly, it also blocks light from reaching the water. This prevents the aquatic plants from photosynthesizing, a process which provides oxygen in the water to animals that need it, like fish and crabs.

• Replacement of desirable fish by less desirable species: Eutrophication has been shown to cause competitive release by making abundant or otherwise limiting nutrients; this causes shifts in the composition of ecosystems. For instance, an increase in nitrogen might allow new, more competitive species to invade and compete with original species .

One of the main problems occurring as a result of algal blooms or other aquatic plants (disproportionate growth, Photo 9) is the reduction in transparency in the water which reduces the recreational value of lakes, particularly for swimming and boating. Water hyacinth and Nile cabbage can cover large areas near the shore and can float into open water spreading at times over the entire surface. These mats can block light to submerged plants and produce large quantities of dead organic matter that can lead to low oxygen concentrations and the emission of unpleasant gases such as methane and hydrogen sulfide due to its decomposition or decay. Masses of these plants can restrict access for fishing or recreational uses of lakes and reservoirs and can block irrigation and navigation channels.

The following are the symptoms and impacts of eutrophication.

1- Increase in production and biomass of phytoplankton, attached algae, and macrophytes

2- Shift in habitat characteristic due to changes in assemblage of aquatic plants

3- Replacement of desirable fish by less desirable species:

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4- Production of toxins by certain algae:

Some algal blooms especially blue-green algae are toxic to plants and animals. This toxicity can lead to decreased biodiversity or it can manifest itself in primary products making its way up the food chain, and marine animal mortality has been observed , and may pose a threat to human.

5- Increasing operating expenses of public water supplies, including taste and odor problems, especially during periods of algal blooms: When raw water supplies contain large amounts of algae and some other aquatic plants, the cost of treatment increases and the quality of the product may decrease. Planktonic algae can shorten filter runs. They can also release organic compounds that cause tastes and odors and, in some instances, serve as trihalomethanes (THMs) and halo acetic acid (HAA) . The compounds react with chlorine during the disinfections process and are considered as human carcinogens.

6- Deoxygenating of water,

especially after collapse of algal blooms, usually resulting in fish kills: When a body of water experiences an increase in nutrients, primary producers reap the benefit first. This means that species such as algae experience a massive population bloom. The increase in algae bloom would increase the amount of oxygen present in the water because oxygen is a product of photosynthesis. Under eutrophic condition, dissolved oxygen is reduced by the dense population. But too much algae block sunlight from reaching deep in the lake. These algae die and become food for the bacteria which use up the oxygen while eating the dead algae. When dissolved oxygen levels decline, especially at night, when there is no photosynthesis, hypoxia occurs and fish or other marine animals may suffocate.

7- **Infilling and clogging of irrigation canals with aquatic weeds** (water hyacinth problem of introduction, not necessarily of eutrophication).

8- Loss of recreational use of water:

Excessive growth of attached algae and aquatic macrophytes can impair swimming, boating, and fishing by interfering with water contact; severe odor problems can also be caused by decaying algae, water weeds, and algal scum .

9- Violations of water quality standards:

During daylight, algal photosynthesis removes CO2 from water which increases the pH, algal respiration in the night releases CO2 and lowers the pH. In late afternoons the pH of excessively fertile water can be found to exceed the water quality standard for pH. Algae produce oxygen during photosynthesis, but they consume it during respiration. Also due to bacterial and other organism respiration, dissolved oxygen concentrations can be below water quality standards for the protection of fish and other aquatic life. Excessively fertile water bodies that thermally stratify often exhibit dissolved oxygen depletion below the thermocline due to bacterial respiration and consumption by dead algae. Richards (1965) showed that one phosphorus atom, when converted to algae, which subsequently dies, can consume 276 oxygen atoms as a part of the decay process . Although oxygen depletion in lakes leads to the death of fish and benthic organisms, the production of undesired chemical species (NH3, H2S, CH4) accelerates cycling of pollutants from sediments, especially P. Oxygen depletion is one of the most important and commonly observed water quality problems in lakes .

10- Water clarity (water transparency):

Water clarity is defined by the depth of the water body at which the bottom sediments can be seen from the surface. Water bodies with high degrees of clarity (the bottom can be seen at depths of 20 or more feet) have low planktonic algal content. In more eutrophic water bodies, the sediments can only be seen at a depth of a few feet. The greenness of water, inorganic turbidity, and high level of planktonic algal chlorophyll diminish water clarity