Eutrophication

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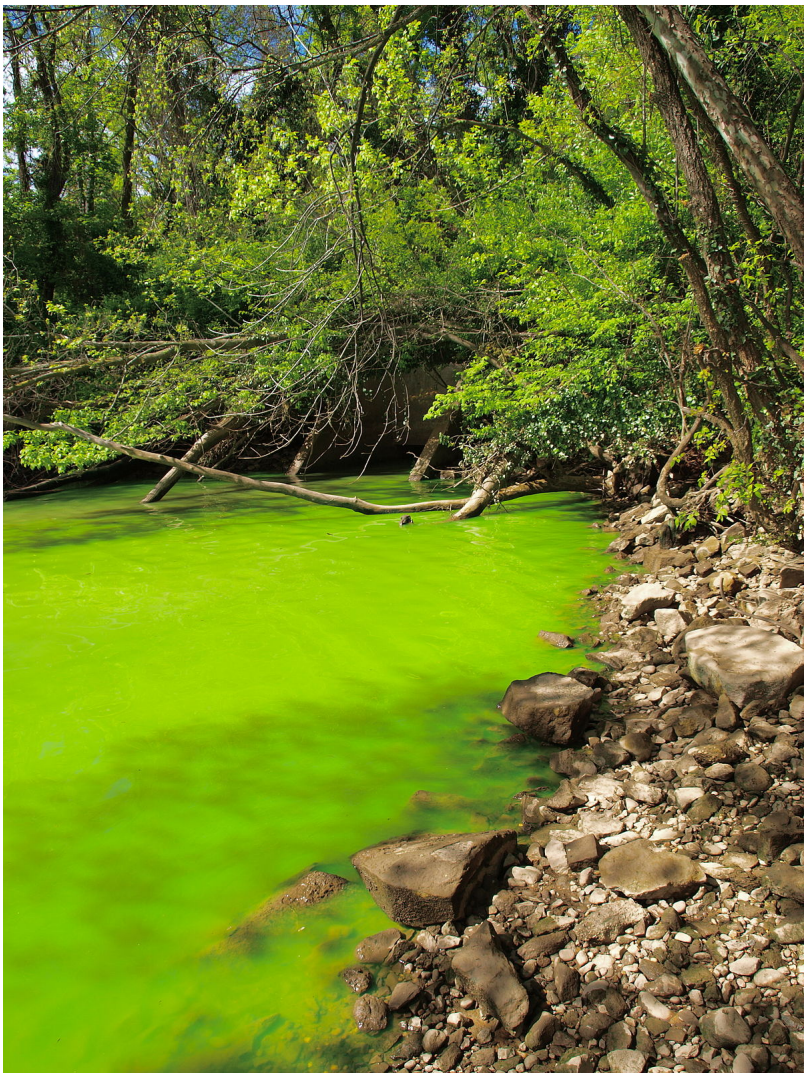

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1 Introduction

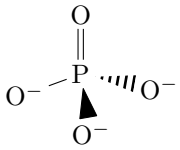
Eutrophication (from the Greek $\epsilon\tilde{\upsilon} + \tau\rho o\phi\acute{\eta}$, "well nourished") is a phenomenon that occurs when a body of water becomes overly rich with minerals and nutrients that encourage excessive growth of plants or algae. This process may lead to oxygen depletion of the water if the amount of oxygen consumed by decomposers overtakes the amount created by producers. Eutrophication is usually caused by the discharge of nitrate or phosphate-containing detergents, fertilizers or sewage into an aquatic system[1].

2 Cause

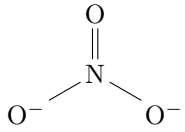
Eutrophication is caused by the release of either nitrates (${NO_3}^{2-}$) or phosphates(${PO_4}^{3-}$) into aquatic environments by the results of human activities. These two chemicals are usually the limiting factors for algae and plant growth, and the addition of these chemicals allows these producers to enter their exponential growth phase, in which growth is governed by the formula

$$\frac{dN}{dt} = r_{max}N \tag{1}$$

These producers eventually die off, usually very close to each other, and increase oxygen consumption through decomposition.



(a) Phosphate



(b) Nitrate

Figure 1: Chemicals that cause eutrophication

2.1 Increased Cellular Respiration

It is through cellular respiration that Oxygen depletion occurs during eutrophication. After the producers created by eutrophication die off, the population of the detritivore population increases dramatically, and with it, an increased occurrence of cellular respiration.

$$C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,H_2O + 6\,CO_2 + ATP \tag{2}$$

Since the detritivore population increases while the producer population decreases, there is more O_2 consumed then there is being produced. Once the oxygen level is low enough, the detritivores start to die off, leaving a eutrophic environment.

3 Consequences

The effects of eutrophication, including increases in CO_2 and increased amounts of dissolved solutes in the water, have many consequences, of which some are a more acidic environment, less oxygen-carrying capacity, and increased ammonia level.

3.1 Decreased pH

The increases in CO_2 levels means that the amount of H_2CO_3 formed also increases.

$$H_2O + CO_2 \longrightarrow H_2CO_3 \tag{3}$$

Since H_2CO_3 is a weak acid, a portion of the Carbonic acid molecules will disassociate into $H^+ + {CO_3}^-$

$$H_2CO_3 \rightleftharpoons H^+(aq) + {HCO_3}^-(aq) \tag{4}$$

3.2 Reduction of the population of organisms

The bloom and subsequent die-off of aquatic plants, algae, and cyanobacteria and the ensuing depletion of oxygen are similar to what occurs in marine dead zones. Such conditions threaten the survival of organisms. One example is of Lake Erie, in which eutrophication coupled with overfishing wiped out the populations of pike, whitefish, and trout by the 1960's[2].

Figure 2: One consequence of eutrophication

3.3 Creation of Algal Blooms

The introduction of excess nutrients introduced by the disposal of human waste and agricultural run-off, especially excess phosphorus, introduces the growth of photosynthetic plants and phytoplankton. The growth of phytoplankton causes reduced light in the lower depths of the water which brings about aquatic dead zones and lessens biodiversity. When algae decomposes, the decomposers deplete the oxygen from the water. The anaerobic environment caused by the decomposition may introduce bacteria that can be toxic to the environment.[3]

References

[1] *Eutrophication*. 2018. URL: https://en.wikipedia.org/wiki/Eutrophication.

[2] J. B. Reece et al. *Campbell Biology*. 9th ed. San Francisco: Pearson Benjamin Cummings, 2011. Chap. 52, p. 1224. ISBN: 9780321558237. CA.

[3] Xiao-e Yang et al. "Mechanisms and assessment of water eutrophication". In: *Journal of Zhejiang University SCIENCE B* (2008), pp. 197–209. DOI: 10.1631/jzus.B0710626. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2266883/.