1.2.6.3 Eutrophication and pollution

Eutrophication is the nutrient enrichment of a system. It occurs when a factor that normally limits productivity no longer acts as a limiting factor. For example adding phosphate to a lake where the concentration of the phosphate is the key factor limiting productivity allows increased formation of organic matter, and the development of eutrophic conditions.

(a) Natural eutrophication: The natural process of lake maturation is that of eutrophication. The original state of all lakes is the oligotrophic condition characterized by low nutrient conditions. But, during the course of time organic sediments and nutrients increase with influx from the surrounding upland. The community diversity increases and the lake changes from an oligotrophic to a mesotrophic and finally to a eutrophic condition (figure 1.2.15).

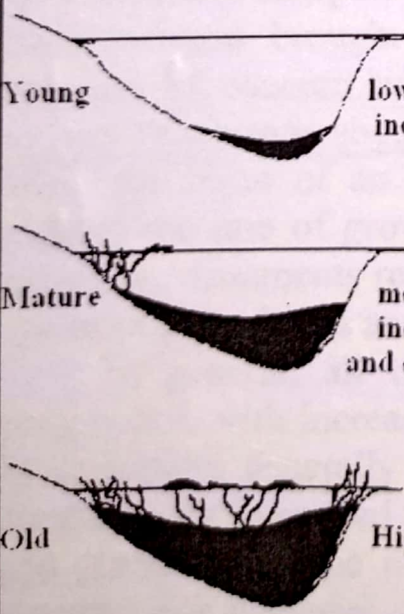
According to Odum (1956), the dynamics of freshwaters can be considered at three levels: the first is a temporal succession; the second is the action of the community; and the third is the long time geological succession through erosion and consequent changes in the basin. The total productivity of the community can be represented as:

$$I_m + P = E_x + R$$

where Im = import; Ex = export; P = productivity and R = respiration

The fundamental dynamics in lake succession involves a change in the balance of these parameters. In the early stages of ecological succession the P/R ratio is greater than one but the total amount of organic matter is low. As succession continues organic matter builds up in the lake representing excess of production over respiration and the lake moves towards the eutrophic stage where P = R.

The quantities of plankton, oxygen concentration and average depths are the first features that undergo change, followed by the bottom



Lake characteristics					
Age	Sediments	Type	Annual NPP (dry g/m²/ yr)	Phytoplankton biomass (dry g/m²)	Total inorganic nutrients (mg/l)
Young	low mainly inorganic	oligotrophic	15-50	<0.2	2-20
Mature	moderate inorganic and organic	mesotrophic	50-150	0.2-0.6	10-200
Old	High	eutrophic	150-500	0.6-10	100-500

Figure 1.2.15 Succession in lakes and changes in characteristics (modified and redrawn from Maitland, 1990).

characteristics and fauna (Table 1.2.7). When a lake has reached the real eutrophic stage, the change towards a greater degree of eutrophy is very speedily effected. Obviously, the smaller the lake, the more rapid is the eutrophication, and subsequent extinction. An average lake whose history is such as to permit eutrophication will be expected to pass from an original oligotrophic stage, during which productivity is low, into the eutrophic stage, in which productivity reaches its maximum, and finally into the dystrophic (senescent) stage, in which the aquatic productivity declines to the stage of complete extinction. Theinemann (1926) states that oligotrophy passes over to eutrophy when the volume of the epilimnion exceeds that of the hypolimnion. Obviously both the organic and inorganic sediments contribute to the process. Thus as the lake ages nutrient enrichment occurs. This is known as natural eutrophication, and is not only confined to lakes but occurs in all types of aquatic systems.

Thus the nutrient capital of the system typically increases during the life of a lake and so an oligotrophic lake slowly becomes eutrophic with time. The process of enrichment or eutrophication, leads to turbid waters, mainly as a result of an increase in the abundance of phytoplankton. Very often these changes are marked by a shift from a clear water community dominated by higher rooted plants or macrophytes to a turbid water community dominated by a dense concentration of phytoplankton.

(b) **Cultural eutrophication**: A different facet of this phenomenon is the cultural eutrophication brought about largely through human activity. Eutrophication becomes of concern when its rate is greatly accelerated by products of human activity that brings about equivalent changes in decades or years. The prime factor being the input of an excess nutrient, which removes the limiting effect, and triggers the rate of growth of organisms. The accelerated nutrient enrichment of aquatic environments results from anthropogenic disruption of the biogeochemical cycles of phosphorus and nitrogen.

In general, all those applying the term eutrophication have used it in conjunction with increases in plant production within lakes as a function of time. Most authors generally agree that this increased plant productivity is associated directly with increased nutrient concentration in lake waters, especially nitrogen and phosphorus. The main reason is a steady increase in man's agro-industrial activity. For instance, a ten-fold increase in the use of fertilizers has occurred, mainly in the developing countries. Thus nutrients pass into the system in the form of industrial effluents, sewage effluent, and as runoff water from surrounding agricultural land where fertilizers have been used.

Table 1.2.7 Characteristics of eutrophic, olgotrophic, and dystrophic lakes (modified from Maitland, 1990).

Characteristics	Oligotrophic	Eutrophic	Dystrophic
1. Basin	Narrow and deep	Broad and shallow	Small and shallow
2. Lake substrate	Stones and inorganic silt	Fine organic silt	Peaty silt
3. Water colour	Green or blue	Yellow or green	Brown
4. Organic content	Low	High	High
5. Phytoplankton	Many species low numbers	Few species high numbers	Few species high numbers
6. Zooplankton	Many species low numbers	Few species high numbers	Few species high numbers
7. Macrophytes	Few species	Many species abundant in shallow water	Few species abundant in shallow water
8. Fish	Few species	Many species	Very few or none
9. Bottom contour	V-shaped	U-shaped	Flat
10. Oxygen	High	Greatly reduced in the hypolimnion	Oxygen scarce at all depths
11. P/R ratio	P/R> 1	P = R	P< R

Another important source is the widespread use of phosphate-based detergents (figure 1.2.16), which ultimately find their way into the water bodies. The process of eutrophication is accelerated and subsequently the water becomes unfit for any use. Human activity also increases the process of erosion so that greater amounts of silt pass into the water body. These enhance the successional process, and the lake is converted rapidly into a shallow pond, marsh and finally into dry land. A process, which would otherwise have taken hundreds of years, is completed in a small span of time, and the lake meets its death (Table 1.2.8).

Most of the early workers in this field have considered nitrogen and phosphorus to be the elements accelerating the process of eutrophication. A shortage of nitrogen and phosphorus generally limits the productivity of freshwater systems, especially phosphorus, due both to its immobilization in the biota and the insolubility of its compounds. If phosphorus alone is increased, the cyanophytes, which are capable of fixing nitrogen, generally dominate the phytoplankton

(c) Methods of controlling eutrophication: There are many measures that can be taken to treat the symptoms of cultural eutrophication (Croll and Hayes, 1988). The methods include the control of point sources of sewage and detergent rich industrial effluent. Sewage as well as industrial effluents can be effectively treated to remove nitrogen and phosphorus (to be discussed later). Another large-scale control is a massive reduction in the use of artificial fertilizers and the adoption of biofertilizers together with farming practices that are conducive to nitrate retention in the soil. Similarly the large-scale use of detergents domestically is another problem and this can be mitigated by using non-phosphate detergents. Proper education and awareness of the common people to the impact of cultural eutriophication is necessary to deal with the problem.

Changing the composition of the community to reduce eutrophication is termed as biomanipulation. Many natural water bodies are described as oligotrophic: clear water ecosystems in which primary and secondary is limited by shortage of the major nutrients. The nutrient capital typically increases during the life of a lake and so an olgotrophic lake may slowly become eutrophic with time. The process of enrichment or eutrophication, leads to turbid waters, mainly as a result of an increase in the abundance of phytoplankton. Very often these changes are marked by a shift from a clear water community dominated by rooted higher plants or macrophytes to a turbid-water community dominated by a dense concentration of phytoplankton. With artificial eutrophication, following a large increase in nutrient supply, the process happens rapidly and the trophic structure of the lake becomes unbalanced. There follows reduction in dissolved oxygen concentrations and changes in the phytoplankton, higher plant and animal communities (Moss, 1988).

The interaction between the plant and animal community are highly complex. Macrophytes are important as a refuge for large zooplankton to escape predation. Planktivorous fish select the larger zooplankton and their activity produces a zooplankton community dominated by smaller species. For these reasons, macrophyte cover is a crucial factor determining the trophic structure of a lake. One effect of removing macrophytes is to lower the average size of the zooplankton.

Through their grazing, zooplanktons are one of the important regulators of phytoplankton abundance. By their excretion, they are also the most important sources for the phytoplankton. Significantly, larger individuals excrete phosphorus at a slower rate, so that a population dominated by small animals will have a higher rate of phosphorus turnover. The size of the zooplankton and the degree of their predation can thus regulate the available phosphorus in the lake, and consequently eutrophication.

This strategy is involved in biomanipulation. The system is tuned for the growth of macrophyte, lower predation of the large zooplankton by increasing the number of piscivorous fish and in some cases, addition of larger species of *Daphnia*. Where the phytoplankton community is dominated by cyanophytes, addition of freshwater mussels, *Dreissna*, as an additional consumer of blue green algae improved the results (Van Donk and Gulati (1991). The technique has been used with partial success to control blue-green algal blooms in some eutrophic lakes (Beeby, 1993).