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Review Article

EUTROPHICATION IN LENTIC SYSTEMS AND ITS IMPACT ON FISHERIES
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Abstract
Water eutrophication has become a worldwide environmental problem in recent years, and understanding the mechanisms of water eutrophication will help for prevention and remediation of water eutrophication. In this paper, recent advances in current status and major mechanisms of water eutrophication, assessment and evaluation criteria, and the influencing factors were reviewed. Water eutrophication in ponds, lakes, reservoirs, estuaries and rivers is widespread all over the world and the severity is increasing, especially in the tropical countries like India. The major influencing factors on water eutrophication include nutrient enrichment, hydrodynamics, environmental factors such as temperature, salinity, carbon dioxide, element balance, etc., and microbial biomass. The occurrence of water eutrophication is actually a complex function of all the possible influencing factors. Eutrophication can cause problems such as bad taste and odour in fishes captured from such waters. Sometimes it leads to the death of all forms of life in water bodies. Eutrophication increases the growth and age structure of planktivorous fish populations in peculiar cases.

Keywords: Eutrophication, Mechanisms, Influencing factors, Nutrient enrichment, Assessment criteria, Water quality, Harmfulness.

1. Introduction
Water eutrophication is one of the most challenging environmental problems in the world. The increasing severity of water eutrophication has been brought to the attention of both the governments and the public in recent years. The mechanisms of water eutrophication are not fully understood, but excessive nutrient loading into surface water system is considered to be one of the major factors (Fang et al., 2004; Tong et al., 2003). The nutrient level of many lakes and rivers has increased dramatically over the past 50 years in response to increased discharge of domestic wastes and from agricultural practices and urban development (Mainstone and Parr2002). Nutrient enrichment, especially phosphorus (P) and nitrogen (N), has been considered as a major threat to the health of water bodies (Andersen et al., 2004). Once a water body is eutrophicated, it will lose its primary functions. The main purpose of this paper is to provide a brief review on recent advances on understanding the mechanisms of water eutrophication and progresses in identifying the influence factors inducing water eutrophication.

2. Water eutrophication – Definition and Meaning
Lakes and estuaries accumulating large amounts of plant nutrients are called “eutrophic” (from the Greek words eu meaning “well” and trophe meaning “nourishment”). Eutrophication can be defined as the sum of the effects of the excessive growth of phytoplanktons leading to imbalanced primary and secondary productivity and a faster rate of succession from existence to higher serial stage, as caused by nutrient enrichment through runoffs that carry down overused fertilizers from agro-ecosystems and/or discharged human waste from settlements (Khan and Ansari, 2005). Water eutrophication can be greatly accelerated by human activities that increase the rate of nutrient input in a water body, due to rapid urbanization, industrialization and intensifying agricultural production. For lake aquatic ecosystems, human activities in the watershed can lead high nutrient turnover, high porosity of nutrients and sediments, and the loss of productivity (Liu and Qiu, 2007). For example, aquaculture is one of many human activities contributing to the environmental decline of natural water bodies and the collapse of fisheries stocks worldwide (Alongi et al., 2003). Because of the influence of several human activities, excessive nitrogen, phosphorus and other nutrients are loaded into water bodies like lake, reservoirs, embouchure and bay, which could cause...
negative ecological consequences on aquatic ecosystem structures, processes and functions, result in the fast growth of algae and other plankton, and deteriorate water quality (Western, 2001). Water eutrophication is caused by the autotrophic algae blooming in water, which composition its bioplasm by solar energy and inorganic substances through photosynthesis. Inorganic nitrogen and phosphorus are the major control factors for the propagation of algae, especially phosphorus (Richardson et al., 2007).

3. Assessment of water eutrophication – Physical and Chemical evaluation

Water quality guidelines have been improved in recent years. Five classes of surface water quality have been set up and some selected parameters for assessing water quality of lakes or reservoirs are shown in Table 1. However, there are no perfect evaluation criteria for assessing water eutrophication. Generally, the physical and chemical evaluation parameters were used to assess water eutrophication, mainly nutrient concentration (N and P), algal chlorophyll, water transparency and dissolved oxygen. Although there are many different assessment parameters, the concentrations of total nitrogen and phosphorus are the two basic ones (CNEPA, 2002). The available parameters concerned include total nitrogen (TN), total phosphorus (TP), Chlorophyll-a, dissolved oxygen (DO), chemical oxygen demand by K2MnO4 oxidation method (CODm), biological oxygen demand (BOD5), etc. (Cheng and Li, 2006). Table 2 shows the critical values of TN, TP, TNI and primary productivity in various eutrophicated water. It has been shown that theeutrophication or red/green tide occurs when N concentration in water reaches 300 μg/L and P concentration reaches 20 μg/L. Richardson et al. (2007) reported that exceeding TP threshold concentration of 15 μg/L causes an ecological imbalance in algal, macrophyte and macro invertebrate community structure. Therefore it is considered that a buffering zone (12–15 μg/L) of TP may be more realistic and protective for all trophic levels.

Table 1: Classification of surface water quality for lakes or reservoir (CNEPA, 2002)

<table>
<thead>
<tr>
<th>Items</th>
<th>Surface water quality classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>Class I: 6.0-7.0; Class II: 7-7.5; Class III: 7.5-8.0; Class IV: 8.0-8.5; Class V: 8.5-9.0</td>
</tr>
<tr>
<td>DO (mg/L)</td>
<td>Near saturation</td>
</tr>
<tr>
<td>CODm (mg/L)</td>
<td>≤2</td>
</tr>
<tr>
<td>BOD5 (mg/L)</td>
<td>≤3</td>
</tr>
<tr>
<td>TN (mg/L)</td>
<td>≤0.2</td>
</tr>
<tr>
<td>NH4-N (mg/L)</td>
<td>≤0.15</td>
</tr>
<tr>
<td>NO3-N (mg/L)</td>
<td>≤0.06</td>
</tr>
<tr>
<td>TP (mg/L)</td>
<td>≤0.01</td>
</tr>
<tr>
<td>Chlorophyll a</td>
<td>≤0.001</td>
</tr>
<tr>
<td>Transparency (m)</td>
<td>≥15</td>
</tr>
<tr>
<td>Escherichia coli (L−1)</td>
<td>≤200</td>
</tr>
</tbody>
</table>

DO: dissolved-oxygen; CODm: Chemical oxygen demand by K2MnO4 oxidation method; BOD5: Biological oxygen demand; TN: Total nitrogen; TP: Total phosphorus.

Table 2: Critical values of N and P in various eutrophicated water (Richardson et al., 2007)

<table>
<thead>
<tr>
<th>Eutrophic status</th>
<th>TP (μg/L)</th>
<th>TN (μg/L)</th>
<th>Primary productivity (mg C/m²/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oligotrophic water</td>
<td>5-10</td>
<td>250-600</td>
<td>5-300</td>
</tr>
<tr>
<td>Mesotrophic water</td>
<td>10-30</td>
<td>500-1100</td>
<td>300-1000</td>
</tr>
<tr>
<td>Eutrophic water</td>
<td>30-100</td>
<td>1000-2000</td>
<td>&gt;1000</td>
</tr>
<tr>
<td>Hypereutrophic water</td>
<td>&gt;100</td>
<td>&gt;2000</td>
<td>&gt;1000</td>
</tr>
</tbody>
</table>

3.1. Biological assessment of eutrophication – A new approach

A set of ecological indicators including structural, functional and system-level aspects were proposed for a lake ecosystem health assessment according to the responses of lake ecosystems to chemical stresses like acidification, eutrophication, and copper, oil and pesticide contamination. The structural indicators included phytoplankton cell size and biomass, zooplankton body size and biomass, species diversity, macro- and micro-zooplankton biomass, the zooplankton/phytoplankton ratio, and the macrozooplankton/microzooplankton ratio. The functional indicators encompassed the algal C assimilation ratio, resource use efficiency, community production, gross production/respiration (i.e., P/R) ratio, gross production/standing crop biomass (i.e., P/B) ratio, and standing crop biomass/unit energy flow (i.e., B/E) ratio. The ecosystem level indicators consisted of ecological buffer capacities, energy, and structural energy (Xu et al., 2001).

4. Influencing factors of water eutrophication

Water eutrophication is mainly caused by excessive loading of nutrients into water bodies like N and P. Excessive nutrients come from both point pollution sources such as waste water from industry and municipal sewage and non-point pollution sources like irrigation water, surface run water containing fertilizer from farmland, etc. The basic cause of water eutrophication is more connected to an imbalance in the load of nitrogen and phosphorus with...
respect to silica (Dauvin et al., 2007). At present, excessive TN and TP in water are considered as the only factors inducing water eutrophication. Rather, nutrient enrichment is only the necessary but not the sufficient condition for algal bloom. Other influencing factors of water eutrophication include: slow current velocity, adequate temperature, other favorable environmental factors, microbial activity and biodiversity (Li and Liao, 2002).

4.1. Nutrient enrichment

There are different opinions on the relationship of nutrient enrichment to water eutrophication and algal bloom: (1) When P concentration in water is low, it may be the limiting factor for inducing water eutrophication and algal bloom; (2) When P concentration in water increases rapidly, other may become a new limiting factor, such as pH, water depth, temperature, light, wave, or other biological factors; (3) The influence of N and P still lasts for a longer time because of the high development level of our society (Zhao, 2004). The “experienced molecular formula” of alga is as “C_{106}H_{263}O_{110}N_{25}P” based on the chemical components of algae. N and P are the two elements which account for least proportion in the molecular formula of algae, especially P; it is the main limiting factor to control the growth of alga in water (Mainstone and Parr, 2002). It was reported that 80% lake and reservoir eutrophication is restricted by phosphorus, about 10% lake and reservoir eutrophication is relative to nitrogen, and the rest 10% lake and reservoir eutrophication is relative to other factors (Zhao, 2004). In many ecosystems, phytoplankton biomass is correlated with the availability of N or P (Cloern 2001; Bledsoe et al., 2004). The composition of phytoplankton species is also affected by the concentrations of N and P (Reynolds, 2006). The ratio of N:P in the water body (referred to as the “Redfield ratio”) is an important indicator of eutrophication. If the Redfield ratio is 16:1 or more, P is most likely the limiting factor for algal growth and lower ratios indicate that N is of great importance (Redfield et al.,1963; Hodgkiss and Lu, 2004). P has been shown to be the principal limiting nutrient for primary production of phytoplankton in many freshwater environments (Phelps, 2002), while N is commonly limiting in marine ecosystems (Cloern, 2001). However, there are many exceptions to this general pattern. The variations in the chemical composition of natural waters are believed to be an important factor in regulating the abundance, composition, geographical and periodic distribution of phytoplankton. It has been considered that the growth of phytoplankton is influenced by dissolved silicate-Si (DSi) concentration in water and its ratio to nitrate (Turner et al., 2003).

4.2. Hydrodynamics

There is no relationship between water disturbance and algal occurrence or its scale, but water disturbing can influence the growth periphytic algae because their blooms grow in relatively stable water. Cai et al.(2007) found that when there is no water to dilute, disturbing water itself can influence the process of eutrophication and species succession, which is not related to disturbing water itself but is influenced indirectly by changing light and nutrient status. In shallow water, increased frequency of disturbance could increase the P release from the sediment, especially at high temperatures (Cai et al., 2007).

4.3. Other environmental factors

In many moderately eutrophicated water bodies, algal bloom occurs in some seasons or some years when the environmental conditions are favorable. The influence of some of these factors is discussed as follows:

4.3.1. Temperature

Temperature induces algal bloom. Alga bloom always occurs at temperature between 23 °C and 28 °C. Statistical analysis shows that the influence of temperature on algal growth rate is the largest. The process of sporangium formation and bursting is hypersensitive to temperature. Under adequate temperature, it can propagate largely and alga bloom will form very fast (Wang et al., 1996).

4.3.2. Carbon dioxide

Carbon dioxide level is one of major factors controlling water eutrophication. Cyanophytes are more capable of utilizing levels of carbon dioxide and become more buoyant at low levels of carbon dioxide and high pH. Some species produce dense mats of vegetation, inhibit the growth of other phytoplankton and also limit the swimming of zooplankton. The reduction of light reaching the lake floor also inhibits submerged and rooted macrophytes, and sediments become anoxic as large amounts of planktonic biomass are added to them (Kant and Raina, 1990). The fluctuations in free carbon dioxide values correspond directly with the fluctuation in the standing crop of phytoplankton. As the diversity and density of phytoplankton increases through various months, the amount of free carbon dioxide for photosynthetic activity becomes limiting. The pH changes in these ponds are governed by the amount of free carbon dioxide, carbon trioxide, and bicarbonate (Kant and Raina, 1990).

4.3.3. Light

Light plays an important role in the growth, diversity and density of aquatic flora. Algal growth has been reported to increase with light intensity, and luminescence of 4000 lux was found most favorable (Shen, 2002). As eutrophication progresses, a decline of submerged macrophytes occur in many shallow water bodies, probably due to low light intensity caused by algal blooming. The light has been almost completely absorbed by the plankton of the top few meters, so that too little light penetrates to the thermocline and beyond to support photosynthesis (Ni et al., 1999).

4.3.4. pH and Dissolved oxygen

There are other factors like pH and dissolved oxygen affecting water eutrophication (Khan and Ansari, 2005). The minima and maxima in the concentration of dissolved oxygen are found to be directly related to the maxima and minima of the phytoplankton. The direct relationship between phytoplankton and dissolved oxygen content has been observed by a number of researchers (Khan and Ansari, 2005). pH is a plant growth limiting factor. The change in pH is directly related to the availability and absorption of nutrients from solution. Ionization of electrolytes or the valence numbers of different ion species are influenced by changes in pH. High pH values promote the growth of phytoplankton and result in bloom.
et al., 2000).

**4.4. Microbial biomass**

Microbial activity is the inducement factor to algal bloom (Paerl, 1998; Paerlet et al., 2003). It can enhance abundant breeding of algal bloom. Nutrient enhanced microbial production of organic matter, or eutrophication, is frequently accompanied by altered microbial community structure and function (Paerl, 1998). The amount of microbial biomass is positively related to the content of organic matter and the amount of plankton in eutrophicated water. There exists a certain intrinsic relationship between the amount of bacteria and the occurrence of eutrophication. The decomposition of organic matter by bacterial activities can produce nutrients and organic substances, which may promote algal bloom (Watson and Ormerod, 2004).

**5. Harmful effects of water eutrophication**

Water eutrophication disturbs the intrinsic equilibrium of the aquatic ecosystem and lead to the damage of the water ecosystem with gradual degeneration of its functions. As a result it can affect water quality and make transparency of water become worse. Thus, little sunlight can penetrate water body and photosynthesis of plants under the water will be weakened or even stopped. Water eutrophication can also cause the super-saturation or lack of dissolved oxygen in water, which will be stressful to aquatic animals and may cause death. Eutrophic systems tend to accumulate large amounts of organic carbon (Dell'Anno et al., 2002). Meanwhile due to water eutrophication, a mass of algae, mainly Cyanophyta and Chlorophyta, bloom and form a thick layer of “green scum” on water surface. Algae can release toxins, consumes dissolved oxygen and render the organic matters in water to be decomposed into harmful gases, which will poison the fish/shellfish. The harmfulness of eutrophication also causes the shortage of drinking water source by degrading water quality. When the blooming algae die, they produce lots of algal toxin which is harmful to human health. Cyanobacterial toxins (cyanotoxins) include cytotoxins and biotoxins which are responsible for lethal, acute, chronic and sub-chronic poisonings of wild/domestic animals and humans. The biotoxins include the neurotoxins; anatoxins, saxitoxins, hepatotoxins, microcystins, nodularins and cylindrospermopsins (Carmichael, 2001).

**6. Impact of eutrophication on the fisheries production of lentic systems – A contradictory case**

Eutrophication can cause problems such as bad taste and odour in fishes captured from such waters. Sometimes it leads to the death of all forms of life in water bodies. On the other hand, it has also been reported that eutrophication increases the growth and age structure of planktivorous fish populations (ICAR, 2011). The increase in total catches incyprinid and silurid populations together with the decrease in percid, clupeid and salmonid, as they are intolerant of such situations. Fish tolerant of higher temperatures and lower oxygen concentrations may increase in production (Lappalainen, 1996). Usually in shallow lakes, dense algal growth out-competes the original aquatic plant beds. This means a loss of living habitats for young fish and a loss of spawning habitats for species that attach their eggs to aquatic plants. The abundance of large invertebrates living on plants, such as snails and insect nymphs, is also much curtailed, reducing the amount of suitable food for many larger carnivorous fishes. Such extreme conditions may be less favourable for cyprinids, too (Moss 1980). Changes in the physical environment induced by eutrophication such as decrease in submerged vegetation, increase in turbidity could affect the competitive interactions predator and prey, especially carnivorous fishes (Persson, 1983; Diehl, 1988). Cyprinids are able to feed efficiently at low light intensities and even in darkness, whereas silurids, percids, clupeids and salmonids are visual hunters as they are dependent on vision (Diehl, 1988). Some highly eutrophic waterbodies also tend to produce large populations of stunted pan fish. This may be the result of inadequate predation on these fish arising from the inability of predators to see them due to increased turbidity from planktonic algae and suspended sediment (Lee et al., 2012).

**7. Future suggestions**

The limited knowledge of water eutrophication processes will add difficulties for the prevention and remediation of water bodies. Therefore, more researches should be turned to the mechanisms of water eutrophication under different watershed conditions.

**References**

drainage ditches of British grazing marshes. Aquatic Conservation, 118(3): 455-466.


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