EUTROPHICATION AND AQUATIC LIFE

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Abstract— Growing of algal blooms and other plants are one of the major problems faced by the water bodies caused due to number of activities done by the humans. This growing of plants is nothing but eutrophication one of the major problems due to which water quality is getting deteriorated and ecosystem is getting destroyed. The foremost effect of eutrophication is on the aquatic life. A large number of species of animals and plants have their shelter under the water and this eutrophication affects them hazardously. Some of the serious defects include fish kills, and also death of some of the aquatic plants. Eutrophication is caused mainly due to addition of nutrients into the water body mainly due to human activities. As this has very serious consequences on aquatic life, it is necessary to scale the causes responsible for eutrophication and hence is necessary to take drastic steps to recover from this serious problem affecting the water life. This paper briefly gives an overview of eutrophication and mainly how it affects the aquatic life.

Keywords— Eutrophication, Algal blooms, Red tides, Fish kills, Dead Zones.

I. INTRODUCTION

The Aquatic Life is the life living under water for almost all its life. It may breathe its oxygen from that dissolved in water through specialised organs called gills, or directly through is skin.

Aquatic animals are often concern to conservationists because of their fragility of their environments. Aquatic animals are subjected to pressure from overfishing, marine pollution and climate change.

Aquatic life is a vast resource, providing food, medicine and raw materials, in addition to recreation and tourism all over the world. It helps in determining the very nature of our planet. Marine life forms a very important part of the ecological cycle, and also they contribute significantly to the supply of oxygen, thus involved in the regulation of the earth’s climate. Nowadays there is an increasing trend towards eutrophication of water bodies worldwide.

Eutrophication is a process which takes place where water bodies receive excessive nutrients which results in excessive plant growth. These plants include algal blooms, and which in turn have a cascade effects on the ecosystems.

These effects may include: algal blooms, growth of undesirable algal species, oxygen depletion at the bottom waters, unpleasant tastes and odors.

Eutrophication is a result of ecosystems responses to human activities that fertilize water bodies mainly with nutrients as Nitrogen and Phosphorous.

These inputs come from a variety of sources as like untreated sewage discharges, sewage treatment plants etc... In some cases the climax stage of algal blooms can release toxic chemicals such as domoic acid to the aquatic environment, creating elevated metabolic risks to a variety of fish and marine mammals.

II. THEORETICAL CONTENTS

2.1 Eutrophication:
A large proportion of all life on Earth lives under water. The habitats studied in marine biology include everything from the tiny layers of surface water in which organisms and abiotic items may be trapped in surface tension between the ocean and atmosphere, to the depths of oceanic trenches. Some of the habitats include coral reefs, seagrass meadows, tidepools, muddy, sandy and rocky bottom. The organisms studied range from phytoplankton and zooplankton to huge cetaceans (whales). These Aquatic organisms are adversely affected due to increased trend of eutrophication.

This eutrophication is nothing but the harmful changes caused in water due to increased nutrients leading to changes in animal and plant populations and degradation of water quality.

Eutrophication is basically a natural process that occurs when a water body or lake ages. However, human-caused, accelerated eutrophication (called "cultural eutrophication") occurs more rapidly, and causes problems in the affected water bodies

An appropriate amount of Nitrogen and Phosphorous are very much important as they are essential components of structural proteins, cell membranes and other molecules that capture and utilize light and chemical energy to support life. This balanced state is disturbed by many human activities that artificially enrich water bodies with N and P, resulting in unnatural and uncontrolled high growth of plants and
other organic matter that degrade water quality and the habitats.

2.2 Types of Eutrophication:
There are mainly two types of eutrophication:

2.2.1 Cultural Eutrophication or Artificial Eutrophication

2.2.2 Natural Eutrophication

2.2.1. Cultural Eutrophication or Artificial Eutrophication:
Cultural or Artificial Eutrophication is basically a process that occurs when human release excessive amounts of nutrients into the water body.

2.2.2 Natural Eutrophication:
Natural Eutrophication is the eutrophication that takes place naturally due to ageing of a particular water body over a period of hundreds and thousands of years.

2.3 Sources of Eutrophication:
Eutrophication mainly occurs from two sources:

2.3.1 Point sources:
In point sources, the nutrient wastes travel directly from source to water. Point sources are relatively easy to regulate.

Point sources (can locate the cause):
- Sewage treatment plant discharges
- Storm sewer discharges
- Industrial discharges

2.3.2 Non-Point Sources:
In Non-Point sources, wastes come from ill-defined and diffuse sources. Non – Point sources are difficult to regulate and usually very spatial with season, precipitation and other irregular events.

Non-point sources (can’t locate the cause, it’s everywhere)
- Atmospheric deposition
- Agricultural runoff (fertilizer, soil erosion)
- Septic systems

2.4. Causes of Eutrophication:
As mentioned in the previous paragraph, eutrophication is caused mainly due to point and non-point sources.

The main causes of Eutrophication are:
- Natural Runoff of nutrients from the soil and the weathering of rocks
- Runoff of inorganic fertilizer (containing nitrates and phosphates)
- Runoff of manure from farms (containing from nitrates, phosphates and ammonia)
- Runoff from erosion (following mining, construction work or poor land use)
- Discharge of detergents (containing phosphates)
- Discharge of partially treated or untreated sewage (containing nitrates and phosphates)
- Urban and Industrial Sources
- Fossil Fuel Sources

Eutrophic events have increased because of the rapid rise in intensive agricultural activities, industrial activities and population growth. These processes generate large amount of nitrogen and phosphorous. These nutrients enter the soil, air and water. Atmospheric sources of nitrogen also contribute to eutrophication. Fossil fuels and fertilizers release nitrogen into the atmosphere. This atmospheric nitrogen is then redeposited on land and water through the water cycle, rain and snow.

2.4.1. Agricultural Sources:
Agricultural nutrient sources include fertilizer leaching and runoff from agricultural fields: manure from CAFOs; and aquaculture operations. Drainage water from agricultural land also contains phosphorus and nitrogen. It usually has much more nitrogen because phosphorus is usually bound to soil components. Extensive use of fertilizers results in significant concentrations of nutrients particularly nitrogen, in agricultural runoff. If eroded soil reaches the water body, both phosphorus and the nitrogen in the soil contribute to eutrophication. Erosion is often caused by deforestation which also results from unwise planning and management of the resource.

2.4.2. Chemical Fertilizers:
Global use of synthetic nitrogen fertilizer and phosphorous is increased on a large scale. Fertilizers are often applied in excess of crop needs. The excess nutrients are lost through volatilization, surface runoff and leaching to groundwater. On average, about 20 percent of nitrogen fertilizer is lost through surface runoff or leaching into groundwater. Synthetic nitrogen fertilizer and nitrogen in manure that is spread on fields is also subject to volatilization.

2.4.3. Manure:
The rapidly changing nature of raising livestock has contributed to a sharp increase in nutrient levels. Animal production is intensifying and as a result, more production is occurring further away from feedstock supplies, making it harder to spread the manure. The large quantity of manure produced by these operations is applied to land as fertilizer, stacked in the feedlot, or stored in lagoons. Frequently an oversupply of manure means it is
applied to crops more than is necessary, further adding nutrients.

2.4.4. Aquaculture:
Aquaculture or Fish farming is another growing source of nutrients and which further contributes eutrophication. Annual aquaculture production worldwide has increased tremendously. Total 43% of all aquaculture production is within marine or brackish environments, with the remainder in freshwater lakes, streams and man-made ponds. Such fish farms generate concentrated amounts of nitrogen and phosphorous from excrement, uneaten food and other organic waste. If improperly managed, aquaculture operations can have severe impacts on aquatic ecosystems as nutrient wastes are discharged directly into the surrounding waters. For every ton of fish, aquaculture operations produce 42 and 66 kg of nitrogen waste and between 7.2 and 10.5 kg of phosphorous waste.

2.4.5. Fossil Fuel:
When fossil fuels are burned, they release nitrogen oxides (NOx) into the atmosphere. NOx contributes to the formation of smog and acid rain. NOx is redeposited to land and water through rain and snow (wet deposition), or can settle out the air in a process called dry deposition. Coal – fired power plants and exhaust from cars, buses and trucks are the primary sources of NOx. Fossil fuel combustion contributes approximately 22 teragrams of nitrogen pollution globally every year.

2.4.6. Urban and Industrial Sources:
Municipal waste water plants and industrial wastewater discharges, nitrogen leaching from below the ground septic tanks, and storm-water runoff are some of the urban and industrial sources of nutrient pollution. These sources are point sources as mentioned above as they discharge nutrients directly to surface waters or ground water. Sewage treatment plants also releases P and N from the treatment process resulting in nutrient pollution. The most prevalent urban source of nutrient pollution is human sewage.

2.4.7. Other causes:
Any factor that causes increased nutrient concentration can potentially lead to eutrophication. In modelling eutrophication, the rate of water renewal plays a critical role: stagnant water is allowed to collect more nutrients than bodies with replenishes water supplies. Also, the drying of wetlands causes an increase in nutrient concentration and subsequent eutrophication blooms.

2.5 Environmental Factors:
A variety of environmental factors are responsible for water eutrophication. Their mechanism influencing the algal blooms varies with the season and other climatic factors. The algal bloom caused by phosphorus inputs also modifies several abiotic factors of the water body. These factors directly govern the growth, diversity and density of biotic components.

Some of the environmental factors that influence eutrophication are:

1) Temperature and Salinity: These are the two important factors to induce algal bloom. These always occur at temperature between 23 °C and 28 °C, salinity between 23% and 28%. The variation of temperature and salinity also affect algal bloom, and an important condition for algal bloom is that temperature increases and salinity decreases faster than ever in short time. Exquisite change of temperature may cause the subrogation of biological communities leading to algal bloom when other environment conditions are adequate. Statistical analysis shows that the influence of temperature on algal growth rate is the largest, followed by salinity and their interaction.

2) Carbon Dioxide: Carbon Dioxide is one of the major factors controlling eutrophication. Carbon dioxide level is one of major factors controlling water eutrophication. Cyanophytes are more capable of utilizing low levels of carbon dioxide and become more buoyant at low levels of carbon dioxide and high pH. It keeps them in the upper layers of the water column with abundant sunlight. In addition, some species produce dense mats of vegetation, inhibit the growth of other phytoplankton, and also limit the swimming of zooplankton. These factors together mean that a slow-moving freshwater ecosystem can rapidly become dominated by blue-green algae, displacing not only members of the phytoplankton but some of the animal community as well. 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. The fluctuations in free carbon dioxide values correspond directly with the fluctuation in the standing crop of phytoplankton. As the diversity and density of phytoplanktons increase 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. Inflow nutrient concentration, inflow volume and inflow water temperature show very regular and reasonable impacts on the quality of lake water reported that monsoons served as a flushing mechanism in two ways: (1) They reduced seasonal eutrophication by nutrient enrichment in summer, and (2) they prevented long-term (annual) accumulation of organic matter in the sediments due to nutrient enrichment in the region. Because of the monsoon-
influenced processes and low phosphorus in the Pearl River estuary, the estuary and adjacent coastal waters of Hong Kong appeared to be more resilient to enrichment of nitrogen.

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 favourable. As eutrophication a progress, a decline of submerged macrophytes occurs in many shallow water bodies, probably due to low light intensity caused by algal blooming. Eutrophication in an estuary is a complex process, and climate change is likely to affect each estuary differently due to interactions with nutrient loading and physical circulation. Hence, it is essential to consider the effects of climate change on the context of individual estuarine function to successfully manage eutrophication.

4) pH and others factors: There are other factors like pH and dissolved oxygen affecting water eutrophication. 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. pH is a plant growth limiting factor. The change in pH is directly related to the availability and absorption of nutrients from solution. It must be pointed out that many factors influencing eutrophication are relative and affect each other.

2.6 Cycle of Eutrophication:

Eutrophication arises from the oversupply of nutrients, which induces growth of plants and algae which, when such organisms die, consume the oxygen in the body of water there by creating hypoxia. The primary limiting factor for eutrophication is phosphate. The availability of phosphate promotes excessive plant growth and decay, favoring algae and plankton and causes severe reduction in water quality. Phosphorus adheres to soil, and hence is mainly transported by erosion.

When algae die, they decompose and the nutrients contained in that organic matter are converted into inorganic form by microorganisms. This decomposition process consumes oxygen, which reduces the concentration of dissolved oxygen. The depleted oxygen levels in turn leads to fish kills and a range of other effects bio-diversity.

The most immediate result of any water body eutrophication is increased growth of microscopic floating plants, algae and the formation of dense mutes of larger floating plants such as water hyacinths and Nile, cabbage. Growth results from the process of photosynthesis which is how the plants generate organic compounds and biomass through the uptake of nutrients such as nitrogen, phosphorous from the soil and water. In this process, light acts as the energy source and carbon dioxide dissolved in water as the carbon source. As a result of the photosynthetic process oxygen is produced. When the plants die they decompose due to bacterial and fungi activity, in the process oxygen is consumed and the nutrients are released together with carbon dioxide and energy. Plants growing in the surface during summer and spring will die during autumn and sink to the bottom where they decompose.

During spring and summer, water bodies are often super-saturated with oxygen due to amount of plants. The oxygen surplus is released is to the atmosphere and no longer available to decompose organic matter. This causes oxygen depletion or anoxia in the deeper layers of water. Oxygen depletion is therefore caused by the shifts in the time and space between photosynthesis and decomposition.

2.7 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.

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 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.

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.

The main effects of eutrophication are thus,

- increase in plant and animal biomass
- increase in growth of rooted plants, e.g. reeds
- Increased algal blooms
- increase in turbidity (cloudiness) of water
- Red tides, water discoloration and foaming
- 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.
- Decrease in the transparency of water
- Development of hypoxic and anoxic conditions (low oxygen levels)

2.8 Prevention of Eutrophication:
Eutrophication poses a problem not only to ecosystems, but to humans as well. Reducing eutrophication should be a key when considering future policy, and a sustainable solution for everyone including farmers and ranchers. While eutrophication does poses problems, humans should be aware that natural runoff which causes algal blooms in the wild, is common in ecosystems and should does not reverse nutrient concentration beyond normal levels.

1. Effectiveness: Sources of nutrients must be identified and evaluated, and then cost-effective methods of controls must be implemented.
2. Minimizing nonpoint pollution: The following steps are recommended to minimize the amount of pollution that can enter aquatic ecosystems from ambiguous sources:

a) Riparian buffer zones: Riparian buffer zones can be created near waterways in an attempt to filter pollutants; sediments and nutrients are deposited here instead of in water.

b) Prevention policy

Laws regulating the discharge and treatment of sewage can lead to dramatic nutrient reductions to surrounding ecosystems.

c) Nitrogen testing and modeling

Soil Nitrogen Testing (N-Testing) is a technique that helps farmers optimize the amount of fertilizer applied to crops. By testing the soil and modeling the bare minimum amount of fertilizer needed, farmers reap economic benefits while the environment remains clean.

d) Shellfish – a unique solution: One proposed solution to eutrophication in estuaries is to restore shellfish populations, such as oysters and mussels. Oyster reefs remove nitrogen from the water column and filter out suspended solids, subsequently reducing the likelihood or extent of harmful algal blooms or anoxic conditions. Filter feeding activity is considered beneficial to water quality by controlling phytoplankton density and sequestering nutrients, which can be removed from the system through shellfish harvest, buried in the sediments, or lost through denitrification.

e) Other Measures:

i. Farmers need to take care with when they able fertilizers, for instance a good time is when it’s frosty.

ii. Also using organic fertilizers is better than inorganic, as they break done and release the nutrients more slowly, such as slurry.

iii. Also Farmers can take care where they apply fertilizers, for instance not to close to a water course.

iv. Reduction in the use of phosphates as builders in detergents

v. Reduction in the use of nitrate containing fertilizers

vi. Implementation of tertiary sewage treatment methods which remove nitrate and phosphate

vii. Improvements in agricultural practices (economizing on fertilizer use and improving land use)

viii. Aeration of lakes and reservoirs to prevent oxygen depletion particularly during algal blooms

ix. Restoration of natural wetlands, efficient nutrient removal

x. Removing phosphate-rich material from affected lakes.

xi. removing phosphate rich sediments by dredging.

CONCLUSIONS

Eutrophication is still developing in most lakes and reservoirs on the Earth instead of the efforts taken to prevent it.

Due to lack of scientific and technological information, particularly in different developing countries, decision makers tend to ignore problems, which are related to the traditional value of the country. Therefore it is necessary to bring the real causes and effect relationship of eutrophication to their attention.

Eutrophication can be avoided by using minimal required amounts of chemical fertilizers or better still do away with them and use natural ones instead. Agricultural fields should not be very close to the water bodies. Extra care should be taken while using fertilizers during monsoons as due to run-off, they get transmitted to the water bodies. Then, they can cause blockage of water ways, death of marine life in breakage of food chain.

Socio economic development of a country depends on people’s income and water availability. Water is already becoming a serious limiting factor in the socioeconomic development in countries with a population of low income and limited access to water. Hence each country needs to give a proper attention to solve problems related to the management of water resources.

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