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Research Note

Aquatic Eutrophication: An Overview of Environmental Nitrogen Pollution

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Abstract

Nonpoint nitrogen pollution that originates from a variety of sources is a leading cause of water quality impairments. Before the agricultural and industrial revolution, the rate of nitrogen supply on earth was limited to the rate of bacterial nitrogen fixation. However, increased human activities have caused a massive increase in available inorganic nitrogen leading to global eutrophication. This nitrogen led eutrophication has introduced a widespread degradation of aquatic habitat. Although, various different sources are responsible for such increase in bioavailable nitrogen, synthetic nitrogen fertilizers have been identified as the major source for such eutrophication. Data suggest that over the past few decades, biologically available nitrogen has been doubled. Data also indicate that over one half of the synthetic nitrogen fertilizer ever produced has been used within the past 15 years. Studies further indicate that between 28% – 54% of lakes around the globe are eutrophic and nitrogen fluxes through rivers have increased by 10 – 15 fold or more. This phenomenon directly or indirectly effects the proliferation of selective primary producers and induces aquatic toxicity, hypoxia or anoxia, and an extensive death of invertebrates and fish. This is the most dramatic expression of aquatic eutrophication. In general, marine organisms seem to be more tolerant to the toxicity of inorganic nitrogenous compounds than freshwater organisms, probably because of the enhancing effect of water salinity on the tolerance of aquatic organismss. This paper presents a general overview of eutrophication of aquatic ecosystems and its implications on aquatic ecological conditions.

Keywords: Aquatic ecosystems, eutrophication, fertilizer, nitrogen pollution, nutrient.

1.0 Introduction

The term "Eutrophication" is derived from a Greek word "eutrophia" meaning adequate nutrition. Excessive addition of nutrients (mostly nitrates and phosphates) to the aquatic ecosystems through fertilizers and sewage may lead to "eutrophication", a condition of excessive nutrient accumulation, leading to aquatic ecological imbalances characterized by enhanced algae and plankton growth along with death of invertebrates and fish.

Eutrophication is the first large issue that led the expansion of modern water chemistry in the 1960s and 1970s (Brezonik and Arnold, 2012). According to the extent of eutrophication, lakes can be classified as oligotrophic, mesotrophic, eutrophic, and hypereutrophic containing average total phosphorus concentration of 8.0, 26.7, 84.4, and > 200 µg per liter; and average total nitrogen concentration of 661, 753, 1875, and > 1875 µg per liter, respectively (UNDP, 2013). The average *chlorophyll-a* concentrations in aquatic plants in these lakes are 1.7, 4.7, 14.3, and 100 – 200 µg /mg, respectively (UNDP, 2013). As compared to nitrogen, phosphorus usually binds to the soil components and thus becomes less accessible in runoffs that reach the streams, lakes, river and seas (UNDP, 2013).

2.0 Mechanism of Eutrophication

Nitrogen is essential for existence of life. All organic substances contain nitrogen. However, the most common form of nitrogen on earth is molecular atmospheric nitrogen, some of which is dissolved in water bodies (lakes, river, ocean, etc.). Living tissues and organic substances contain only about .002% of the nitrogen on the planet (Schlesinger, 1997). Nitrogen is also a limiting factor to primary productivity of the earth's ecosystems (Vitousek and Howarth, 1991; Corredor *et al*., 1999).

Nonpoint nitrogen pollution that originates from a of variety sources is a leading cause of water quality impairments (Kaushal *et al*., 2011). For the most part, eutrophication is an induced phenomenon mostly driven by excessive nitrogen and phosphorus in water bodies due to human activities (Howarth *et al*., 2005; Howarth and Marino, 2006). However, it can be a natural process in areas that are prone to seasonal rain and flood. Human agricultural and industrial activities accelerate the rate at which nutrients are incorporated into the environment.

In 1909, German scientist Fritz Haber discovered the process of ammonia synthesis. This energized an enormous global agricultural expansion known as the green revolution (Charles, 2005). Before the agricultural and industrial revolution, the availability of biologically reactive nitrogen on earth was mostly through bacterial nitrogen fixation, and partly due to reaction with oxygen under high temperatures, such as lightning and volcanic activities (Vitousek *et al*., 1997). In recent years, increased human activities have caused a massive increase in available inorganic nitrogen, leading to global eutrophication.

Agricultural activities contribute to aquatic nitrogen pollution by direct runoff from agricultural lands and from animal wastes. The estimated rate of contamination through surface runoff is about 30% of the rate of nitrogen application to the field (Smith *et al*., 1997), and about 30% of the nitrogen from such agricultural lands is volatilized to the atmosphere

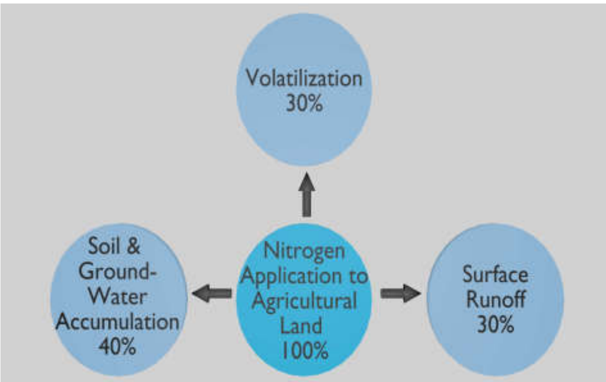

Figure 1: Estimated nitrogen contamination through land application of synthetic fertilizers

in the form of ammonia (Howarth, 2002). Nitrogen fertilizer has been implicated as the single biggest factor in altering global nitrogen cycle (Howarth, 2008). Figure-1 illustrates an estimated nitrogen contamination through land application of synthetic fertilizers.

Data indicate that human activities have increased the rate of global reactive nitrogen formation by 33 – 55% (Boesch, 2002) and most of the nitrogen loading comes from land based sources (Nixon *et al*., 1996). Although, various different sources are responsible for such increase in bioavailable nitrogen, synthetic nitrogen fertilizers have been identified as the major source for such eutrophication. Over one half of the synthetic nitrogen fertilizer ever produced has been used within the past 15 years (Howarth, 2008) and as a result, biologically available nitrogen in nature has been doubled. Atmospheric deposition of nitrogen from fossil fuel combustion is the other considerable contributor to environmental nitrogen pollution. And even though, in some regions it is the largest single source of nitrogen pollution, on a global basis, it is much smaller as compared to nitrogen contribution by synthetic fertilizer. Besides surface runoff, aquatic ecosystems may also receive between 1 – 40% of nitrogen through direct atmospheric deposition (Paerl, 1997; Paerl and Whitall, 1999).

3.0 Effects of Aquatic Eutrophication

The most common occurrence of ecological nitrogen imbalance in the aquatic ecosystems is the excessive bloom of phytoplankton and algae in response to increased levels of nutrients. This phenomenon depletes aquatic oxygen, leading to hypoxic to anoxia conditions, and killing fish and other aquatic animal populations. However, an opposite effect may also occur on some selective aquatic organisms such as population growth of Nomura's Jellyfish which primarily resides between the waters of China and Japan (Yellow Sea and East China Sea). Overall, marine organisms seem to be more tolerant to the toxicity of inorganic nitrogenous compounds than freshwater organisms, probably due to the ameliorating effects of water salinity (sodium, chloride, calcium and other ions) on the tolerance of aquatic animals (Camargo and Alonso, 2006).

In general, eutrophication supports excessive growth of simple algae and planktons over higher plants. These algae and planktons utilize other nutrients needed for higher aquatic plants and animals. Excessive surface algal growth inhibits sunlight for submerged plants. When these algae die, they sink to the bottom where they are decomposed by bacteria. This decomposition process also utilizes oxygen and causes hypoxic to anoxic conditions leading to the death of other aquatic organisms. Bacterial action also converts organic nutrients into inorganic substances. Figure-2 illustrates a generalized view of aquatic eutrophication through nitrogen pollution.

Eutrophication also causes other disruptions such as change in water color to red, yellow or brown, decreasing the value of water bodies for fishing or recreation and may interfere with drinking water supply. A United Nations survey indicates that between 28% – 54% of lakes around the globe are eutrophic (ILEC, 1988-1993). The most important economic impacts of eutrophication include human sickness, extensive kills of aquatic animals, and loss of recreational and tourism industries.

Drinking water polluted with nitrites and nitrates has been linked to methemoglobinemia (inhibited oxygen-carrying capacity of hemoglobin), cancers of the digestive tract, non-Hodgkin's lymphoma, bladder cancer, ovarian cancer, birth defects, diabetes mellitus, thyroid hypertrophy, and respiratory tract infections. Health effects due to algal toxins are nausea, vomiting, diarrhea, pneumonia, gastroenteritis, hepatoenteritis, muscular cramps, and poisoning syndromes (Camargo and Alonso, 2006).

4.0 Conclusion

Over the past several decades, the earth is experiencing large increases in riverine nitrogen fluxes to coastal waters, and in the US, most of the coastal waters are moderately to severely affected from nitrogen pollution (Hong, 2013). Therefore, it is very important to comprehend and characterize this pollution phenomenon and search for promising solutions.

Eutrophication is considered to be the most widespread water quality problem affecting fresh waters and coastal seas. Most estuarine scientists agree that it is mostly caused by increasing inputs of nitrogen and phosphorus in the aquatic ecosystems, and they also agree that this influx of nitrogen and phosphorus is due to fertilizers applied to agricultural land and wastes from livestock. However, they have less agreement on how to control this pollution. Many studies indicate that reduction of phosphorus inputs successfully reverse the lake eutrophication (Schindler and Vallentyne, 2008), whereas other studies indicate that limiting phosphorus does not

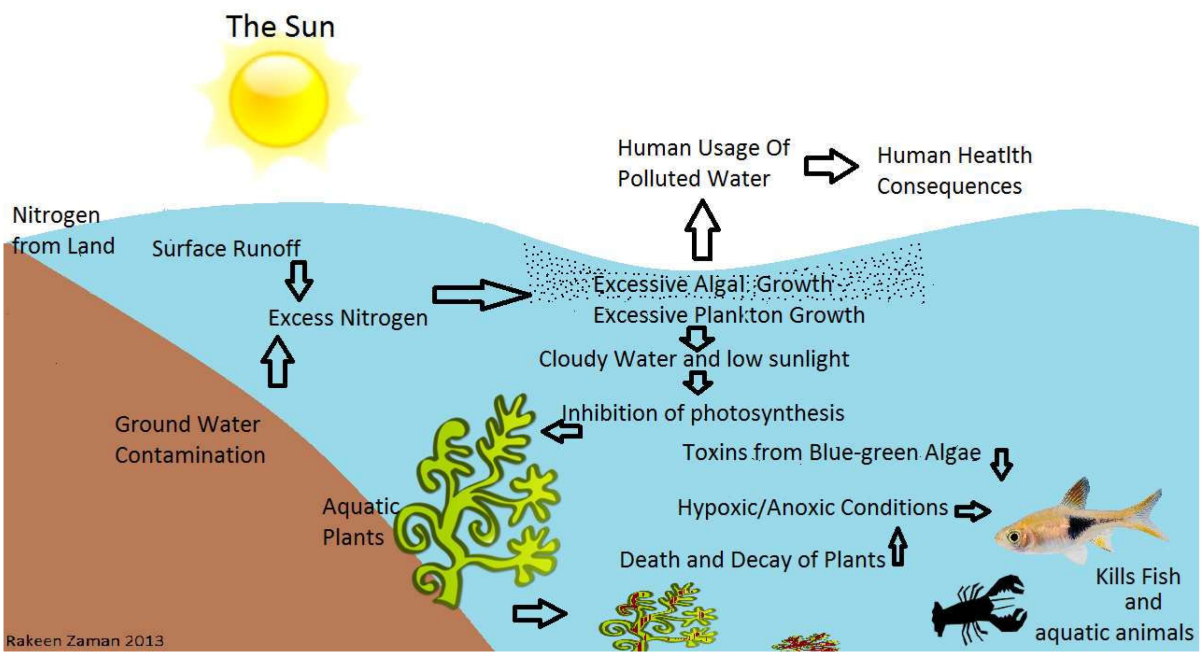

Figure 2: An illustration of aquatic eutrophication through nitrogen pollution

reduce eutrophication (Schindler, 2012). Most scientists agree that it is more important to reduce nitrogen instead, or as well as phosphorus (Howarth and Marino, 2006), however, there are no long-term case studies supporting this view (Schindler, 2012). The European Union now requires that input of both elements to be reduced in coastal waters and similar recommendations have been made to protect coastal ecosystems in the USA (Schindler, 2012). So far, most studies conducted on eutrophication are short-term studies. Sufficient long-term studies are needed to better understand the role of anthropogenic nutrients in eutrophication process and develop the course of action to reverse such a detrimental process which is adversely affecting global aquatic ecosystems.

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