NITROGEN POLLUTION CONCERN OF FRESH WATER AND POSSIBLE MITIGATION MEASURES

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Abstract: Nitrogen is nutrient that is natural part of aquatic ecosystems. Nitrogen is also the most abundant element in the air we breathe. Nitrogen support the growth of algae and aquatic plants, which provide food and habitat for fish, shellfish and smaller organisms that live in water. But when too much nitrogen enters the environment usually from a wide range of anthropogenic activists', the air and water can become polluted. Nitrogen pollution has impacted many streams, rivers, lakes, bays and coastal waters for the past several decades, resulting in serious environmental and human health issues, and impacting the economy. This review article therefore focuses on nitrogen related pollution concern in fresh water body's and source based possible mitigation measures.

***Index Terms* -Nitrogen, Pollution, fresh water, Mitigation, Nutrients.**

I. INTRODUCTION

All organisms require nitrogen to live and grow. It is essential component of cellular materials which are base for growth, enzymatic production, and genetic information (DNA, RNA, and proteins) [1]. However, atmospheric nitrogen, the inexhaustible reservoir of molecular nitrogen, is not chemically available form of nitrogen element for most organisms. This is because of the strong triple bond between the nitrogen (N) atoms in molecular nitrogen (N_2) makes it relatively unreactive, whereas organisms need reactive nitrogen to be able to incorporate it into cells. The symbiotic relationship between bacteria and host plants or some independent algae is needed to change molecular nitrogen into chemically available form.

The rise of chemically available nitrogen waste stream, due to population growth and rapid industrialization, has increased the concern of receiving water health. The human contribution to nitrogen pollution, for instance in the form of urine, is ever increasing in the light of the growing world population [2] [3]. The industrialization, mainly production of synthetic nitrogen fertilizer from atmospheric molecular nitrogen by the Haber - Bosch process, has also significantly increased nitrogen waste stream by anthropogenic nitrogen fixation and increased overall municipal nitrogen waste stream concern.

The element nitrogen is the building block of life, exists in both inorganic and organic forms as well as many different oxidation states. The most common organic nitrogen in municipal wastewater is urea (NH_2CONH_2) [4]. Although fresh, domestic wastewater is rich in urea. Urea is a major chemical component of urine and is the most abundant contributor of nitrogen in typical municipal wastewater treatment plant [4]. In the sewer system, hydrolysis of urea by microorganisms results in the release of ammonium. The main inorganic nitrogen compounds, which are the concern of wastewater treatment plant operation, include ammonium, nitrate and nitrite.

The main nitrogenous wastes that deteriorate the receiving water quality are ammonium (NH_4^+), nitrate (NO_3^-) and nitrite (NO_2^-) [5] [6]. This resulted to an increased attention for nitrogen pollution concerns and development of method and systems by which wastewater can be recycled and used sustainably. This article therefore revises and summaries nitrogen waste source, nitrogen cycle in waste water, and nitrogen related pollution concern in fresh water body's and recommends different mitigation measures.

II. SOURCES OF NITROGEN WASTES

In general, the Cause of nitrogen pollution excess nitrogen from point and non-point source [7]. The main source of excess nitrogen can be summarized as depicted in **table 1** below:

Type of Source	Description
Agriculture	• The nitrogen in animal manure and chemical fertilizers are important to plant grow. However, when this nutrient is not fully utilized by plants it can be lost from the farm fields and negatively impact downstream water quality.
Storm water	• As result of rain on our cities and towns its runoff across hard surfaces likes rooftops, sidewalks and roads which include pollutant nitrogen carries into local waterways.
Waste Water	• Sewer and septic systems are responsible for treating large quantities of waste, and these systems do not always operate properly or remove enough nitrogen before discharging into waterways.
Fossil Fuels	• Electric power generation, industry, transportation and agriculture have increased the amount of nitrogen in the air through use of fossil fuels.

Table 1 Source of Nitrogen Pollutants

III. NITROGEN CYCLE IN WASTEWATER

Wastewater nitrogen cycle is the movement of chemically available form of nitrogen from living organisms to activated sludge process and its return to the atmosphere as wastewater treatment plant by product [8] [9]. The cycle involves change in oxidation states of nitrogen element and incorporates both the organic and inorganic nitrogen. Amino acids and proteins are organic form of nitrogen. Molecular nitrogen, ammonium ions, ammonia, nitrate ions, and nitrite ions are inorganic form of nitrogen.

The kinematics of biochemical reaction in the cycle can be affected by environmental factories that influence microbial activity, such as temperature, dissolved oxygen and availability of Short Chained Fatty Acids (SCFAs). Wastewater nitrogen cycle, mainly involves nitrogen fixation and uptake through organismal growth, nitrogen mineralization through hydrolysis, deamination and decay, nitrification and denitrification processes as shown **Figure 1** below.

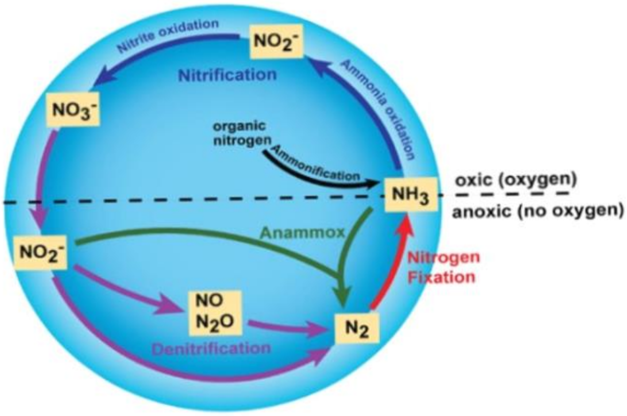

Figure 1. Wastewater nitrogen cycle (www. Nature.com)

A) NITROGEN FIXATION AND UPTAKE

Nitrogen fixation, the process in which molecular nitrogen converted into chemically available form ammonium ion (NH_4^+), is biochemical reaction within nitrogen fixing bacteria. It is a product of symbiotic relationship between the bacteria and the host plant. The bacteria use photosythetically produced energy directly from plant to fix molecular nitrogen in ammonium ion, while the plant obtain produced ammonium ion. The obtained ammonium ions are assimilated into plant material in the form of amino acid and proteins with in tissues, roots and seeds [1]. The plant may be also consumed and pass its ammonium ions along the food chain, or the plant may die and decompose. The process of assimilation and possible transfer of ammonium into food chain is called nitrogen uptake.

B) NITROGEN MINERALIZATION PROCESS

Large quantities of nitrogen wastes discharged into municipal activated sludge process. The organic nitrogen, amino acid and protein with in plant tissue, roots and seeds, can be received into sewer system directly in the form of garbage disposal waste and food processing wastewater or indirectly in the form of fecal waste. In sewer system biochemical reaction takes place and some of amino acid and protein convert into inorganic ammonium ions. This process is called deamination or ammonification. Similarly N, the largest constituent of urea, which can be found in urine, fertilizers and stock yard wastes hydrolysis into ammonia and carbon dioxide by enzyme called urease [10] [11]. In addition, amino acids and proteins that are not degraded in the sewer system may be degraded into ammonium ion in the aeration tank. The overall biochemical process, deamination, hydrolysis, and aeration tank degradation, which consume organic nitrogen and generate inorganic ammonium nitrogen is called nitrogen mineralization.

C) NITRIFICATION PROCESS

The fates of ammonium ions as result of nitrogen mineralization may be include being used as a nutrient source for nitrogen by heterotrophic bacteria. Nitrifying bacteria, air-stripped to atmosphere as ammonia at high PH, and under appropriate operational conditions, *nitrosomonas* may also oxidize them to nitrite and then to nitrate by nitrobacteria. The oxidation of ammonium nitrogen into nitrite and then into nitrate in an aeration tank under appropriate operation is called nitrification as depicted in eq.(1)&(2) [4] [1].

$$\mathrm{NH_4^+} + 1.5\mathrm{O_2} \rightarrow \mathrm{NO_2^-} + 2\mathrm{H^+} + \mathrm{H_2O} \qquad (1)$$

Subsequently, AOB convert NH_4^+ into NO_2^- and NOB transform NO_2^- into$NO_3^-(1)$:

$$\mathrm{NH_4^+} + 1.3\mathrm{NO_2^-} \rightarrow 1.02\mathrm{N_2} + 0.26\mathrm{NO_3^-} + 2\mathrm{H_2O} \qquad (2)$$

Several operational conditions are satisfactory for nitrification to occur. These conditions mainly include the substrate (ammonium and nitrite) for nitrifying bacteria, adequate dissolved oxygen, adequate hydraulic retention time of the wastewater in the aeration tank, and a healthy and active population of nitrifying bacteria. It is more easily occurs in the presence of high MLVSS and high temperature.

The two types of nitrification processes that may be occur in the aeration tank are complete and incomplete (partial) nitrification. Complete nitrification is desirable form of nitrification as part of activated sludge process that can be achieved, when the ammonium concentration and the nitrite concentration in mixed liquor effluent are less than $1\mathrm{mgL^{-1}}$ each and the nitrate concentration is as high as possible [4] [1]. In contrast, several limiting factors can be responsible for occurrence of incomplete nitrification. High influent ammonium concentration, short retention time in the aeration tank, inhabitation and temporary low dissolved oxygen level are some of operational factors responsible for its occurrence [1].

D) DENITRIFICATION PROCESS

In wastewater treatment plants, nitrite and nitrate need to be used as electron acceptor in order to meet a total nitrogen discharge limit of nitrification-denitrification process. An anoxic reduction of nitrite and nitrate back into molecular nitrogen gas (N_2) in anoxic condition is called denitrification as described in Eq.3. MLVSS and nitrate ions produced in aeration tank are conveyed to the denitrification tank along with soluble cBOD such as methanol. Denitrification may also occur in the sludge blanket of secondary clarifier when an anoxic condition develops in the sludge blanket. Even through several groups of organisms are capable of denitrification, the most denitrifying organisms consists of facultative anaerobic bacteria. These organisms have the enzymatic ability to use free molecular oxygen, nitrite or nitrate to degrade ammonium [12] [13] [14]. The use of nitrite or nitrate provides the bacteria less energy for cellular activity, growth, and reproduction than does the use of free molecular oxygen. The genera *alcaligenes, bacillus, and pseudomonas* contain the largest number of facultative denitrifying bacteria.

$$C_5H_{10}O_5 + 4NO_3^- + H^+ \rightarrow 5CO_2 + 7H_2O + 2N_2 \quad (3)$$

IV. NITROGEN POLLUTION RELATED CONCERNS

These N are the most important pollutant nitrogenous compounds that discharge into fresh water body .The discharge of nitrogen wastes into the natural water bodies can lead to significant adverse impacts [4]. The main nitrogenous wastes that deteriorate the receiving water quality are ammonium (NH_4^+), nitrate (NO_3^-) and nitrite (NO_2^-) [4]. The significant quality concerns related to the discharge nitrogenous waste into natural water bodies include eutrophication, dissolved oxygen depletion, toxicity, and indirectly blue baby syndrome (Methemoglobinemia). The pollution concerns of different nitrogenous wastes in fresh water bodies summarized in **Table 2**.

Nitrogenous ion	Description	Pollution concerns
NH_4^+	Ammonium	Blooms of aquatic plants Dissolved oxygen depletion Toxicity
NO_3^-	Nitrate	Blooms of aquatic plants Dissolved oxygen depletion Toxicity
NO_2^-	Nitrite	Blooms of aquatic plants Dissolved oxygen depletion Toxicity

Table 2 Active Nitrogen Pollution Concerns

V. POSSIBLE MITIGATION MEASURES

Municipal wastewater treatment effluent with high contents of nitrogen may have several adverse effects that range from human health hazard to ecological as well as other environmental effects [4].

Source of pollution	Possible Mitigation Measures
Agriculture	• Adopting Nutrient Management Techniques • Ensuring Year-Round Ground Cover • Planting Field Buffers • Implementing Conservation Tillage • Managing Livestock Access to Streams • Engaging in Watershed Efforts
Storm water	• Adopting Green infrastructure techniques include rain gardens, pervious pavement, rain barrels and green roofs.
Waste Water	• Adopting regular system inspection and pumping tank • Ensuring efficient use of water • Avoiding household hazardous waste disposal into toilet • Ensuring waste water treatment quality
Fossil Fuels	• Conserving Energy • Using Renewable Energy • Increasing Energy Efficiency • Managing and Reducing Emissions

Table 3 Nitrogen Pollution Mitigation Measures

VI. CONCLUSION AND RECOMMENDATION

In conclusion, As result of ever increasing anthropogenic influences, enormous amount of nitrogen containing wastewater has been discharged into different water bodies with little or no treatments throughout the world. Due to significant pollution concerns related to this waste stream, the need for effective and efficient mitigation measures to the adverse consequence of water pollution is evident. This resulted to an increased attention for nitrogen pollution concerns. Finally, to mitigate nitrogen pollution impact, my recommendation summarized in to the following major points:

1. Pollution sources should be managed to reduce waste generation.
2. Enhancing effective and efficient mechanism of Nutrient usage.
3. More systems and methods should be developed to ensure sustainable use Nitrogen waste.
4. Chemical quality of effluents should be check to ensure no disposal of excess nitrogen into recipient water bodies.cf

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