Fundamental methods to eliminate organic nitrogen from sewage water: A comprehensive analysis

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ABSTRACT

Adulteration of hydrosphere is a rapidly expanding natural challenge. Certain noxious environmental and illness are associated with nitrogen pollution in various water sources, especially in younger age groups. As a result, most of the nations have imposed rigid norms over the concentration of azote compounds in sewage water. Sewage water processing involves energy-intensive and expensive organic processes that transforms azote compounds into innoxious azote gas. However, on the contrary, Nitrogen is a key constituent of amino acids, which are, as well considered as the fundamentals of proteins, and nucleic acids, those are the basic unit of genetic material (RNA and DNA). Synthetic composts are generated by fixing aerial nitrogen gas in an energy consuming organic process. Preferably, the usage of chemicals and energy should be at minimal level in order to eliminate the nitrogen from sewage water. Also, it should be able to restore some composts and manures. This review gives an outline about different organic nitrogen elimination methods that involves oxidation of ammonium compounds, reduction of nitrates and nitrites, and anammox reaction, also, bio electrochemical systems for nitrogen extraction and growth of microphytes.

1. Introduction

Groundwater and other water bodies are adulterated with azote compounds. As fertilizer use in agriculture increases, it has been reported in Canada that about 293,000 tonnes of nitrogen per year contaminate surface and groundwater. In addition, when various types of waste such as industrial waste, animal waste, and domestic waste flow into untreated water bodies, it causes water pollution. Municipal wastewater treatment facilities (WWTPs) also generate about 80,000 tonnes of nitrogen pollution per year to surface and groundwater [1]. Many countries have strict nitrogen emission standards. For example, in the United States, wastewater treatment plants should emit below 5 mg/L of ammonium and 15 mg/L of entire nitrogen. Therefore, nitrogen removal from wastewater

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is vital for water conservation, especially in areas experiencing water scarcity. Eutrophication of running water environ is one of the undeviating and fatal effects of unlimited nitrogen loading. Accumulation of minerals and nutrients in water leads to the degradation of freshwater ecosystems due to the rapid increase of algae in the waterbodies, the growth of aquatic plants, oxygen reduction and loss of critical species. Moreover, cyanobacterial flowers can generate naturally occurring contagion that can have adverse effects on mankind [2]

Nitrogen is present in various oxidation states, making its elimination from the hydrosphere more complex. Processing by surface assimilation or co-precipitation is commonly impractical owing to nitrate's high stable establishment and solubility, resulting in dynamic and cost to treat nitrate-adulterated water. Majority of the sewage water processing systems have two levels of treatment: principle treatment (physical aggregation of solids) and subordinate treatment (different forms of organic oxidation, e.g., sludge or bacterial sieves). In sectors, where norms require higher sewage water quality, the 3rd level processing is carried out to eliminate nutrients and disinfect. Tertiary processing acts as a final purifying process that eliminates inorganic compounds and ameliorate sewage water quality before reusing, recycling, or released into the nature [3-5].

Biological point of view is known to be productive in eliminating azote compounds from sewage water. The most widely used biological sewage water processing method, triggered sludge, was made to enhance nutrient elimination efficiency. In a general nitrogen elimination process, sewage water goes through nitrification and denitrification (Escudero et al., 2015). Nitrification is the organic degeneration of ammonia and then nitrite is converted into nitrate, denitrification abates nitrate. It eventually generates N_2 through a chain of NO intermediates. Inadequate biological C origin in sewage water for denitrification will adversely affect nitrogen elimination efficiency. Previously, various techniques for the nitrification and denitrification of wastewater were considered [6].

This analysis, points to collate the power efficiency and expense to facilitate sewage water policy judgement centred on restricted circumstances expectantly. Direction. We will talk about the fundamentals of nitrogen elimination process, in sewage water processing plant; for example, oxidation of ammonium compounds, denitration and anammox formation. It represents a collating point of view of the advantages and disadvantages of different nitrogen elimination process, including good quality sewage water and chemical-energy restoring prospects [7-8]. Moreover, we will also focus on different biochemical factors that may lead to have effect on organic N_2 elimination process depicted in figure 1.

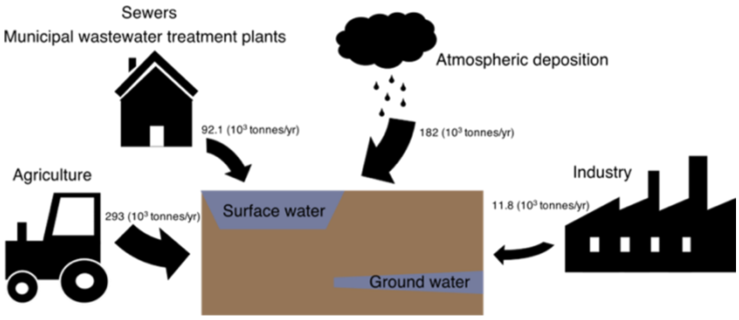

Fig. 1: Sewage water and chemical-energy restoration cycle.

Source: https://www.sciencedirect.com/science/article/pii/S0734975020300677

2. The Nitrogen Cycle's main biological enzyme process that changes nitrogen into its many oxidation Forms:

Stein et.al. [9]proposed 5 nitrogen conversion streams, which are represented by coloured arrows in Fig. 2(A), namely dinitrogen reduction or ammoniation with nitrogen fixation (red line), assimilation of nitrate to ammonium, and assimilation reduction (Dissimilatory Nitrate Reduction to Ammonium)(indigo line). Nitrification (green line and orange line arrows) consists of oxidation of ammonia to nitrite and nitrite to nitrate; Formation of nitrogen gas from nitrate & nitrite reduction (purplish arrow); Combination of nitridation-denitrification [Anammox (pink arrow)]; Interconversion of nitrites & nitrates (orange and blue arrow) [10]. The transport of reactive nitrogen through the biosphere is finished by the generalize process of mineralization of organic materials and absorption by cell life. The heterotroph denitrifying bacteria, the autotroph nitrifying bacteria, the anaerobic bacteria, and the micro-algae are the microorganisms that participate in the organic processes of the nitrogen cycle that were previously described.

Organic nitrogen and ammonium are the two main types of nitrogen found in water used in initial wastewater treatment. These two fundamental forms of nitrogen are quickly transformed into nitrates during secondary processing by nitrifying bacteria, such as ammonium-oxidizing bacteria (AOB) and nitrite-oxidizing bacteria (NOB). Ammonia can be converted to nitrate using a

recently discovered complete ammonia oxidizer (comammox). The shortest-lived version of nitrogen in the ecosystem is nitrite. It can be found in surface water and wastewater treatment systems as the most prevalent type of inorganic nitrogen. Here, the biological nitrogen cycle mechanisms of nitrification, denitrification, anammox, and nitrogen absorption are covered. The production of clean water resources depends heavily on these pathways.

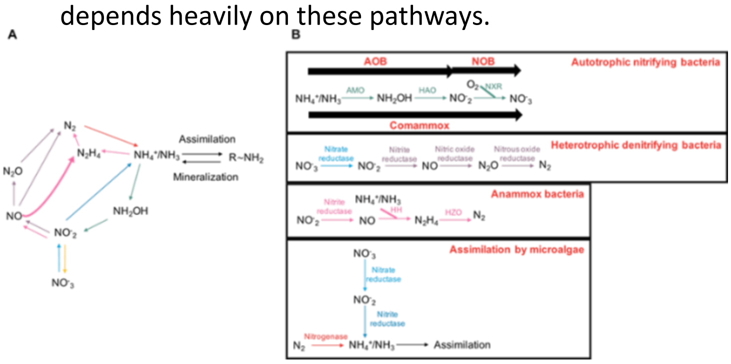

Figure 2: The Nitrogen Cycle's main biological enzyme process that changes nitrogen into its many oxidation forms.

Source: https:// doi.org/10.1016/j.cub.2015.12.021.

3. Basic methods for removing nitrogen:

Depending on the cooperation of microscopic organisms in the microbial population, natural wastewater approach/test is carried out. Therefore, understanding nitrogen removal methods and the microbial populations engaged in these processes is crucial. *Pseudomonadota* are the most prevalent kind of activated sludge and the most widely used wastewater treatment method, guided by other microbial communities such the *Bacteroidetes, Chloroflexi, Actinobacteria, Planctomycetes, Firmicutes*, etc. [11].

A. Nitrification:

One of the most important processes in the nitrogen cycle, which takes place in soil, is nitrification. It is also an aerobic process that requires two subsequent oxidation events, the first of which turns ammonia into nitrites, followed by the second of which turns nitrites into nitrates.Ammonia (NH_3) or ammonium (NH_4+) are predominantly converted into nitrites (NO_2-) and later nitrates (NO_3–) via the biological process of nitrification. Two different energy-producing processes are utilised in its method, which is also used to fix carbon dioxide.

B. Nitrification and Denitrification with Activated Sludge:

The activated sludge technique, which utilizes nitrification-denitrification to eliminate nitrates, is the most used method for removing nitrogen from wastewater. Under aerobic circumstances, ammonia is first oxidised to nitrites and then changed to nitrates. Next, under anaerobic environments, heterotrophic or autotrophic bacteria convert nitrate to positive nitrogen gas. Throughout this procedure, sewage is extensively aerated to provide microorganisms which decompose soluble natural materials. Few organic material develops new cells, while others oxidize. These newly formed cells are then taken out from the flow of water and inserted in the sedimentation tank as sludge, a portion of this sludge is then reintroduced to the aeration tank. The remaining material is useless. Because aeration requires compressed air, traditional activated sludge methods use a lot of energy and need regular maintenance.

C. Microalgal Growth:

Simple organisms known as microalgae produce useful metabolites like lipids, proteins, carbohydrates, and biologically active substances, and they can double overall biomass in just 24 hours. It can be extracted from sewage and used as animal feed and fertilizers. Since more than 50 years, microalgae have been utilized as energy-intensive nitrogen removal; nevertheless, reviving microalgae as a resource can be time and money consuming [12-18].

D. Bioelectrochemical Systems (BESs):

Bioelectrochemical systems (BES) use the engagement of microorganisms with solid electron acceptors for the removal of pollutants such as nitrogen from sewage from power generation. Various wastewater streams and processes for resource recovery are being studied. Although organic matter can be effectively removed from low-load sewage, its effectiveness depends upon the property and concentration of the sewage, hydraulic residence time, and reactor configuration [19].

4. Microorganisms Involved in Fundamental Nitrogen Removal Processes:

Microorganisms & Bacteria play a significant role in natural or industrial nitrogen fixation or even wastewater containing Nitrogen [20-22]. In order for the nitrogen cycle to function, at least four separate types of bacteria known as

- The cause of deterioration,
- Nitrifiers,
- Denitrifiers,
- Fixers for nitrogen are needed,

Microorganisms such as bacteria, fungi, actinomycetes, and cyanobacteria aid in the conversion of nitrogen and the formation of ammonia.

Item fits within the category are:

Non-symbiotic cyanobacteria: Nitrogen in the air can be fixed by unrestricted organisms. As an illustration, Nostoc and Anabaena assist in this procedure.

Symbiotic cyanobacteria: Aids in the fixation of nitrogen. Nostoc is present in the coralloid roots of Cycas, Anabaena is present in the leaves of the water fern Azolla, and Frankia is connected to the stems and leaves of Alnus.

Non-symbiotic bacteria: The process of fixing nitrogen is also aided by naturally occurring soil microbes. Both Azotobacter and Beijerinckia are aerobic, unrestricted bacteria that can fix nitrogen.

Symbiotic bacteria: They have a sizable role in nitrogen fixation. Leguminous plant roots and rhizobium bacteria work together to produce nutrients. *R. phaseoli* and *R. leguminosarum* are crucial organisms that produce root nodules

Microscopic organisms	The part they played
Azotobacter	Helps to fix nitrogen in the soil
Rhizobium	Aids to fix nitrogen in root nodules of leguminous plants
Cyanobacteria	Non-symbiotic bacterial genome plays an essential role in soil nitrogen fixation.
Decay bacteria	Formation of ammonia
Fungi	Formation of ammonia
Nitrosomonas	Ammonia to nitrite conversion.
Nitrobacter	Nitrites to nitrates conversion
Pseudomonas	Denitrification

5. Economic efficiency of biochemical methods for sewage water processing In contrast to the biochemical sewage water processing:

Organic N_2 elimination by oxidation of ammonia & denitration is economically effective. However, there are some cons, such as reduced nitrification, owing to ammonium and organic overload, essential for controlling O_2, aerobic reactors for nitrification &anaerobic reactor for denitrification. Moreover, full elimination of NH_4+ require large reactor or big hydraulic holdings because of slow nitrification rate, leading to high processing expenses [23-24]

The different elimination methods of organic N_2 from sewage water systems have been constructed to reduce the power expense of the process.

- Nitrification and denitration at a same time
- Anammox formation
- Half denitrification and nitrification
- Aerobic demonization,
- Total autotrophic N_2 removal for nitrates.
- O_2 limited nitrification and denitrification
- Membrane bioreactors and cell immobilizatio

Half nitrification through nitrite offers certain advantages in organic wastewater processing over conventional nitrification; The Process Includes:

- A minimum of 40% deduction in COD & denitrification rate of 1.5 to 2 times in the next denitration step,
- A minimum of 25% saving of oxygen utilization, 300% deduction of biomass, & 20% in carbon dioxide emission while denitrification.

When partial nitrification is associated with anammox, the ammonium is partially oxidized to nitrite aerobically, & the rest ammonium then interacts with nitrite to form nitrogen gas in an anaerobic way.

This has certain merits, for e.g. no external carbon source is required, 80% reduced sludge generation, less energy, and 60% lower O_2 requirements than conventional nitrification and denitrification.

6. Nitrogen elimination from industrial sewage water by MABR:

Membrane bioreactor (MABR) sewage treatment uses microorganisms to nitrify and denitrify sewage water, similar to activated sludge. However, MABR utilizes a self-aspirated, coiled plate with a bigger surface area to passively supply O_2 in spite of manually incorporating air into the water.

The expensive air compression process, which uses between 40 and 60 percent of the power in current methods, is eliminated by aeration, which is carried out close to atmospheric pressure [26].

Thin plate /sheet take merits of biofilms, a tenacious natural coating of microorganisms that develops on the membrane's O_2-enriched surface, where bacteria can utilize oxygen most effectively. Prior to being utilized by microorganisms, the majority of air bubbles float to the top during bubble aeration.

The anoxic conditions in the remaining portions of the MABR tank were maintained to allow the anaerobic denitrifying microorganisms to function in the tank just like the aerobic bacteria.

SND method allows a small trace to be generated, collated to traditional techniques needing many cavities.

During processing of activated sludge plant often need guided personnel. Moreover, smart device can control and monitor units.

While many promising processes for nitrogen elimination are still a matter of research. MABR is an examined methodology available in several configurations for sewage water processing plant ameliorate. D & projects dedicated projects and circulated applications.

7. Conclusion:

The recovery of a significant amount of the organic matter s biogas and the reduction of the energy needed for aeration, make the partial nitrification and anammox for initial sewage treatment an appealing proposal. Nevertheless, this idea is challenging since anammox bacteria grow slowly at cold conditions. So, winter operating climates continue to be difficult for full-size operations. Another factor that is identified as needing more research is the method's long period durability. Anammox and partial nitrification both depend heavily on stable nitrite generation to function properly over time. To sustain nitrite generation for various wastewater components and functional environments, it is therefore necessary to further research effective tactics like organic carbon and reaction time, among others.

The presence of nitrates in the wastewater is another issue with anammox procedures. The anammox bacteria's inability to inhibit NOB function will cause them to create nitrate, meaning that the wastewater may need additional treatment. This problem can be solved by a SNAD process that carries out partial nitrification, anammox, and denitrification all at once. Nevertheless, these circumstances significantly complicate current nitrification and denitrification processes. Therefore, a thorough chemical analysis must be performed in order to identify the harmful chemicals present in nitrate-enriched industrial wastewater and then a suitable treatment method must be developed. Effective methods for reducing the negative impacts of hazardous

components in nitrate-enriched industrial effluent include pelletized or biofilm-based systems.

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