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NUTRIENT REMOVAL IN DIFFERENT KINDS OF ARTIFICIAL WETLANDS

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ABSTRACT

NH3 volatilization, nitrification, denitrification, nitrogen fixation, plant and microbial uptake, mineralization (ammonification), nitrate reduction to ammonium (nitrate-ammonification), anaerobic ammonia oxidation (ANAMMOX), fragmentation, sorption, and desalination are just a few of the processes that affect nitrogen removal and retention during wastewater treatment in constructed wetlands (CWs). However, only a few procedures remove complete nitrogen from wastewater, whereas the majority of activities just transform nitrogen to other forms. Total nitrogen removal ranged between 40 and 55 percent in the investigated kinds of built wetlands, with removed load ranging between 250 and 630 g N m2 yr1 depending on CW type and inflow loading. The mechanisms that cause the elimination, on the other hand, vary in magnitude across systems. Due to their inability to offer both aerobic and anaerobic conditions at the same time, single-stage artificial wetlands cannot achieve significant total nitrogen removal. Vertical flow built wetlands effectively remove Ammonia-N, however denitrification is extremely restricted in these systems. Horizontal-flow built wetlands, on the other hand, offer favourable circumstances for denitrification, but their capacity to nitrify ammonia is restricted. As a result, several kinds of built wetlands may be mixed to take use of the distinct benefits of each system. The phosphorus cycle in soil differs significantly from the nitrogen cycle. There are no valency changes during inorganic P biotic absorption or organic P breakdown by microbes.

KEYWORDS: *Constructed, Wetlands, Nitrogen, Phosphorus, Standing Stock, Wastewater.*

1. INTRODUCTION

Constructed wetlands are engineered systems that are planned and built to help treat wastewater by using natural processes including wetland plants, soils, and their associated microbial assemblages[1]. They are intended to mimic many of the activities that occur naturally in wetlands, but in a more controlled setting. Wetlands that are "man-made," "manufactured," or "artificial" are synonyms for "built."The fundamental categorization is based on the kind of macrophysics development, with additional classification based on the water flow regime being the most common[2]. The paper focuses on constructed wetlands with free-floating plants (FFP), free water surface CWs with emergent plants (FWS), and subsurface CWs with horizontal (HSSF or HF) and vertical (VSSF or VF) flows because data on CWs with floating leaved plants and submerged plants is still scarce, making sound evaluations impossible.

Nitrogen has a complicated biogeochemical cycle including seven valence states (+5 to 3) and numerous biotic/a biotic reactions. A range of inorganic and organic nitrogen forms are among the chemicals, which are required for all biological existence. Ammonium is the most common inorganic type of nitrogen in wetlands[3]. In this paper, the main nitrogen reactions in wetlands are discussed. Nitrogen in its many forms is constantly engaged in chemical transitions from inorganic to organic molecules and back again. Some of these activities need energy (usually obtained from an organic carbon source), while others produce energy that organisms utilize for growth and survival. All of these changes are required for wetland ecosystems to operate properly, and the majority of chemical changes are regulated by the living organisms that benefit from them producing enzymes and catalysts.

Ammonium-N is reported to be in balance between gaseous and hydroxyl forms during ammonia volatilization, a physicochemical process[4]. If the pH is below 7.5, losses of NH3 via volatilization from flooded soils and sediments are negligible, and losses are seldom severe if the pH is below 8.0. At pH 9.3, the ratio of ammonia to ammonium ions is 1:1, resulting in substantial losses due to volatilization. During the day, elevated pH levels are frequently caused by algal photosynthesis in wetlands and photosynthesis by submerged macrophytes. The overall respiration activity of all heterotrophic organisms present, as well as the gross photosynthesis of the species present, have a significant impact on the pH of shallow flood water[5].

Ammonification (mineralization) is the biological conversion of organic nitrogen to ammonia. A complicated, energy-releasing, multi-step biochemical process converts ammonia from organic molecules. Microbes utilize this energy for growth in certain instances, and ammonia is directly absorbed into microbial biomass. Organic nitrogen is easily transformed to ammonia in high amounts (up to 100 percent). The ammonification process is basically an amino acid catabolism that involves a variety of deamination processes[6]. The biological oxidation of ammonium to nitrate, with nitrite as an intermediary in the reaction chain, is known as nitrification. When heterotrophic microorganisms are present, this concept has certain limits, but it is sufficient for autotrophic and dominating species.

Although heterotrophic nitrification has previously been linked with chemoautotrophic bacteria, it is now known that heterotrophic nitrification occurs and may be significant. In both nitrate-reducing systems, different numbers of electrons are utilized in the reduction of one molecule of nitrate: 5 in denitrification and 8 in nitrate-ammonification. As a result, nitrate-ammonifying bacteria may oxidize more organic matter per molecule of nitrate than denitrifying bacteria. Furthermore, nitrate reduction is usually carried out by fermentative bacteria that do not need nitrate for development under anaerobic circumstances[7]. As a result, nitrate-ammonifying bacteria may thrive in nitrate-depleted environments.

Denitrification is a bacterial process in which nitrogen oxides (in ionic and gaseous forms) serve as terminal electron acceptors for respiratory electron transport from a biochemical standpoint. Electrons are transported from an electron-donating substrate (typically, but not always, organic molecules) to a highly oxidized N form through various carrier systems. Following phosphorylation, the resulting free energy is stored in ATP and utilized by denitrifying organisms to sustain respiration. The following equation illustrates denitrification. Denitrifies with the same set of electron transport systems may perform aerobic respiration using oxygen as an electron acceptor or anaerobic respiration utilizing nitrogen. This ability to operate as both an aerobe and an anaerobe is very useful because it allows rapid denitrification to occur shortly after the start of anoxic conditions (redox potential of approximately 300 mV) with little change in the microbial population.

Because denitrification is almost entirely carried out by facultative anaerobic heterotrophs that use oxidized N forms instead of O2 as electron acceptors in respiratory processes, and because these processes follow aerobic biochemical pathways, calling denitrification an anaerobic process can be misleading. It's one that takes place in an anoxic environment. The conversion of gaseous nitrogen (N2) to ammonia is known as nitrogen fixation. Nitrogen fixation necessitates the presence of nitrogenize, an oxygen-sensitive iron, sulfur, and molybdenum-containing enzyme complex that also reduces other substrates with triple covalent bonds. Biological N2 fixation in wetland soils may occur in the floodwater, on the soil surface, in aerobic and anaerobic flooded soils, in plant root zones, and on the leaf and stem surfaces.

The majority of the biomass, as well as the nitrogen it contains, decomposes, releasing carbon and nitrogen. This release is significant in the wetland nitrogen cycle because part of the nitrogen is returned to the wetland waters, while others are exposed to aerobic processes in above-water standing dead plant debris and litter, and still others may be translocate to rhizome[8]. Oxidative reactions such as nitrification are favored by above-water breakdown. Because of the belowground storage, the residue from rhizome breakdown and decomposition is further buried. As a consequence of the transport of nitrogen via plants, processes other than those in the soil, water column, and related biofilms are enhanced.

The net productivity (growth rate) of the plant and the concentration of nutrients in the plant tissue restrict the plant's potential rate of nutrient absorption. Plant tissue nutrient concentrations, as well as the final capacity for biomass accumulation: that is, the maximum standing crop, are all factors that influence nutrient storage (standing stock). Rapid growth, high tissue nutrient content, and the capacity to achieve a large standing crop are therefore important characteristics of a plant employed for nutrition absorption and storage. Through a cation exchange interaction with detritus, inorganic sediments, or soils, ionized ammonia may be absorbed from solution. The adsorbed ammonia is weakly linked to the substrate and may readily be released when the water chemistry changes.

A set quantity of ammonia is adsorbed on and saturates the available attachment sites at a particular ammonia concentration in the water column. When the concentration of ammonia in the water column is decreased (for example, due to nitrification), some ammonia will be desorbed in order to reestablish equilibrium with the new concentration[9]. When the amount of ammonia in the water column rises, the amount of adsorbed ammonia rises with it. Sorbed ammonium may be converted to nitrate if the wetland substrate is exposed to oxygen, such as via periodic draining. The ammonium ion (NH4 +) is adsorbed on clays as an exchangeable ion, chemisorbed by humic compounds, or fixed inside the clay lattice.

These responses seem to be happening at the same time. Several variables, including the type and quantity of clays, alternating submergence and drying, nature and amount of soil organic matter, duration of submergence, and presence of flora, are said to affect the pace and intensity of these responses. Through the process of peat formation and burial, certain fractions of the organic nitrogen absorbed in detritus in a wetland may become unavailable for further nutrient cycling. Organic nitrogen burial values have been recorded for a variety of natural wetlands, however there is almost no data available for artificial wetlands. In built wetlands with open water surfaces, where algal assemblages may generate high pH values throughout the day via their photosynthetic activities, volatilization may be a major pathway for nitrogen removal. pH may approach N10.0 during the day in systems with large populations of plankton or periphytic algae, giving ideal conditions for ammonia volatilization[10].

2. DISCUSSION

Ammonification does not eliminate nitrogen from wastewater in treatment wetlands; rather, it transforms organic nitrogen to ammonia, which may subsequently be used by other processes (e.g., nitrification, volatilization, adsorption, and plant absorption. Ammonification occurs during the breakdown of wetland plant biomass and occurs in both aerobic and anaerobic environments. Ammonification happens in all kinds of artificial wetlands as a result. Similarly, to ammonification, nitrification does not remove nitrogen from wastewaters.

Nitrifying bacteria that live in the air. Although nitrification happens in all kinds of artificial wetlands, the degree to which it occurs is controlled by the availability of oxygen. Because ammonia is the main nitrogen species in sewage and many other wastewaters, nitrification is a limiting process for nitrogen removal from most kinds of artificial wetlands. Nitrate-ammonification is arguably the least researched process of nitrogen change in wetlands, and little is known about its involvement in the treatment process. Because nitrate team monification occurs in the presence of low redox potential values, it has the potential to be significant in treatment wetlands where anaerobic conditions exist, such as treatment wetlands with horizontal subsurface flow. Regardless of our current understanding of the process, nitrate-ammonification does not eliminate nitrogen from wastewater.

In most kinds of artificial wetlands, denitrification is considered a significant nitrogen removal process. However, since nitrate concentrations in wastewater are often extremely low (with the exception of drainage water from agriculture and certain industrial wastewaters), denitrification must be combined with nitrification. Different oxygen needs for nitrification and denitrification are a significant stumbling block in many treatment wetlands' attempts to achieve greater nitrogen removal. Under certain climatic circumstances, gaseous nitrogen fixation may play a major role in the nitrogen cycle in wetlands. Nitrogen transformed to organic molecules is released into the water during the decomposition of nitrogen-fixing organisms.

This mechanism is overlooked when evaluating nitrogen removal in built wetlands for wastewater treatment, and there are currently little data available. However, it seems that in systems with free water surface fixation may occur intensely through blue-green algae fixation (cyanobacteria). In built wetlands with free-floating macrophytes, plant absorption is the primary removal method. Emergent plant potential is limited, particularly in artificial wetlands used to treat municipal or household sewage. However, harvesting emergent plants seems to be a major removal pathway in tropical areas where seasonal translocations are low and repeated harvest is feasible, particularly for weakly laden systems.

Ammonium adsorption is only possible in built wetlands with subsurface flow and good substrate-to-wastewater contact. Furthermore, most substrates utilized in built wetlands do not offer a significant number of sorption sites. Currently, the clayey soils that are most efficient in ammonia sorption are seldom utilized in built wetlands. Organic nitrogen burial as a nutrient removal method is limited to manmade wetlands with emergent plants and a free water surface, where the peat/litter layer plays a key role in nutrient removal. The removal efficiency is comparable in all systems, with FFP CWs having a slightly greater removal efficiency because to repeated harvesting.

Total nitrogen removal in the investigated kinds of built wetlands ranged from 40 to 50%, with removed loads ranging from 250 to 630 g N m2 yr1 depending on CW type and inflow loading. It's also worth noting that SSF systems have considerably greater input concentrations since they're often utilized as a secondary treatment step, while FFP and FWS systems are typically employed as a tertiary treatment stage. As a result, in SSF systems, outflow TN concentrations are greater. In addition, since HSSF wetlands often handle diluted wastewaters from combined sewage systems, input TN concentrations in VSSF CWs are greater than in HSSF wetlands. The similar trend has been discovered for loadings.

Inflow loading of built wetlands is compared. In order to obtain a greater treatment impact, several kinds of built wetlands may be combined, particularly for nitrogen. Hybrid systems, on the other hand, are most often made up of staged VSSF (VF) and HSSF (HF) systems. However, there is an increasing desire to achieve completely nitrified effluents. Because of their low oxygen transfer capability, HF systems are unable to do so. VF systems, on the other hand, offer favorable nitrification conditions, but there is no denitrification in these systems. As a result, hybrid systems have piqued people's attention (also sometimes called combined systems).

The benefits of the HF and VF systems may be used to complement each other in combination systems. It is feasible to generate a low-BOD effluent that is completely nitrified and partially denitrified, resulting in much lower total-N contents. In wetlands, phosphorus is found as phosphate in both organic and inorganic molecules. The only type of phosphorus thought to be directly used by algae and macrophytes is free orthophosphate, which provides a key connection between organic and inorganic phosphorus cycling in wetlands. Polyphosphates, which are linearly condensed and cyclic, are another class of inorganic phosphorus compounds. Phospholipids, nucleic acids, nucleoproteins, phosphorylated sugars, and organic condensed polyphosphates all include organically bound phosphorus.

Wetlands offer an environment for all types of phosphorus to interconvert. Plants take absorb soluble reactive phosphorus and convert it to tissue phosphorus, or it may get sorbed to wetland soils and sediments. If the organic matrix is oxidized, organic structural phosphorus may be liberated as soluble phosphorus. Under some conditions, insoluble precipitates develop, but they may re-dissolve under other conditions. The majority of phosphorus is absorbed by plant roots; absorption via leaves and shoots is limited to submerged species and is typically insignificant. Phosphorus absorption by macrophytes is often greatest during the start of the growing season (in most areas, early spring), just before the maximum growth rate is reached. After the plant decays, phosphorus is transferred back into the wetland environment.

At least two mechanisms are involved in the breakdown of aboveground litter and the subsequent release of nutrients into the water. Abiotic leaching is responsible for the first loss of soluble components. This is a fast process that accounts for the bulk of mass loss in the early stages of decomposition. Many wetland plants have shown that leaching causes a fast initial release of nutrients, with up to 30% of nutrients lost by leaching alone during the first few days of decomposition. Released nutrients may be absorbed into the protoplasm of decomposer organisms, where further nutrient losses are accounted for by processes such as respiration and denitrification. Peat/soil accretion is the most important long-term phosphorus sink in wetlands, although it may only be successful in treatment wetlands with significant biomass output and water covering the sediment, such as free water surface built wetlands with emergent plant.

In systems where wastewater comes into contact with a filter substrate, phosphorus adsorption and precipitation are effective. This implies that built wetlands with subsurface flow have the best chance of removing phosphorus via these processes. Horizontal-flow systems have a greater potential than those systems because the substrate is continuously flooded and the redox potential in the bed does not fluctuate significantly. Because the oxygenation of the bed may induce desorption and subsequent phosphorus release, vertical-flow systems, where wastewater is supplied occasionally, may not be as effective. However, materials like as washed gravel or crushed rock, which are frequently used for sub-surface flow CWS, have a relatively limited capacity for sorption and precipitation.

3. CONCLUSION

Total nitrogen removal in the investigated kinds of built wetlands ranged from 40 to 50%, with removed loads ranging from 250 to 630 gNm2 yr1 depending on CWs type and inflow loading. The mechanisms that cause the elimination, on the other hand, may vary in magnitude across systems. Due to their inability to offer both aerobic and anaerobic conditions at the same time, single-stage artificial wetlands cannot achieve significant total nitrogen removal. Vertical-flow built wetlands effectively remove Ammonia-N, although denitrification is extremely restricted in these systems. Horizontal-flow built wetlands, on the other hand, offer favorable circumstances for denitrification, but their capacity to nitrify ammonia is restricted. As a result, several kinds of built wetlands may be integrated (hybrid systems) to take use of the unique benefits of each system. Sorption, precipitation, plant absorption (with subsequent harvest), and peat/soil accretion are the main phosphorus removal mechanisms. However, the sole non-saturable process, soil accretion, occurs exclusively in FWS CWs. unless specific substrates with high sorption capacity are utilized, phosphorus removal in all kinds of artificial wetlands is limited. Total phosphorus removal ranged from 40 to 60% in all kinds of built wetlands, with removed loads ranging from 45 to 75 g Nm2 yr1 depending on the CW type and inflow loading. The amount of nitrogen and phosphorus removed by harvesting emergent vegetation's aboveground biomass is small, but it may be significant in weakly laden systems.

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