Nitrogen in Wetlands

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Contributor: Noreen Khalid

Wetlands are viable sinks for nitrate and have also been identified as a source of nitrous oxide, a product of two microbially regulated processes: nitrification and denitrification. Anthropogenic expansion of nitrogen is a leading cause of the eutrophication of water bodies and may also contribute to the deterioration of the ozone layer in the stratosphere. Wetlands ameliorate the quality of water percolating through them, by retaining nutrients and sequestering carbon, and simultaneously enhancing the flora and fauna diversity of these landscapes. Among the many services these wetlands provide, they also alleviate nitrate pollution by attenuating reactive nitrogen from agricultural drainage and ensure the effective reclamation of the wastewater.

Keywords: Wetland

1. Introduction

Various aquatic ecosystems have encountered a deterioration of water quality due to surplus nutrients stacking, from both point and nonpoint sources. Since 2008, sanitation concerns have imperiled the existence of about 2.5 billion individuals across the globe, through water contamination or direct contact [1]. To optimize pollutant removal, numerous natural wetlands that have recently operated as wastewater disposal sites are expeditiously being altered for agricultural and infrastructure advancement, and considering the upstream treatment of wastewaters utilizing constructed wetlands is an alternative that can be exploited to establish a sustainable supply of cleansed water. Compared to conventional mechanical treatment systems, constructed wetlands productively incorporate the treatment of wastewater, as well as resource enhancement, at a cost-effective rate (60–95%).

Point source pollution alludes to pollutants that come from a definite, traceable source. Whereas, nonpoint source pollutants may appear in untraceable runoff from agriculture, mining, oil, and gas operations, and are laborious to evaluate as they originate from diverse landscapes and various diffuse sources. Pollutants deriving from agricultural runoff introduce dissolved organic carbon, nitrogen, phosphorus, pesticides, salts, sediments, and trace elements into the ecosystem [2]. It has long been established that an abundance of nitrogen, along with phosphorous, is responsible for the eutrophication of coastal waters, estuaries, and inland waters [3][4]. Nitrogen is applied to arable land as inorganic fertilizers, manure, and urea, however, in tile drainage nitrate-N is the major nitrogen form, whereas all other forms are transformed into nitrate-N via hydrolysis and nitrification.

Powlson and Addiscott [5] indicated urea as the most frequently used nitrogen fertilizer. After application, urea is hydrolyzed to ammonia-N within a few days, and if not absorbed by plants, ammonia-N is nitrified to nitrate-N within a month. Nitrate is a chemically inert form of nitrogen and can effortlessly be leached off from the soil profile [6]. Tillage practices have been proclaimed to affect nitrate leaching to a great magnitude. This nitrate leaching effect is distinctively variable, and the consequences are the highest when tillage takes place just before a high-water recharge. Wetlands act as biofilters that help eliminate particulate matter, as sinks collecting nutrients, and also as transformers turning these nutrients into various gaseous forms of nitrogen [7]. The ability of natural wetlands to retain nitrogen was first reported in the 1970s [8]. Acreman [9] evaluated the accessible results from 54 natural wetlands in Africa, Asia, Australia, Europe, and North America and estimated that 80% of these wetlands removed an average of 67% nitrogen. The significant processes accountable for retaining nitrogen are denitrification, nitrogen uptake by plants followed by nitrogen amassing in the plant biomass, sedimentation, and volatilization.

Over the 20th century, wetlands have been broadly viewed as biological filters, providing security to water resources, such as estuaries, groundwater, lakes, and streams. Even though natural wetlands have served as ecological buffers, the research and development of wetland treatment technology is a fairly recent phenomenon, as very little information has been obtained about their biological principles and underlying ecological functioning. Nevertheless, the expanded demands on wastewater treatment effectiveness and the rising cost of traditional treatment systems correspondingly required a better comprehension of wetland treatment operations. Hence, in 1974 the emergence of the first operative horizontal subsurface flow constructed wetland led to the commencement of studies of the viability of employing wetlands for wastewater treatment during the 1950s in Germany.

2. What Are Wetlands?

Cowardin et al. [10] put forth a systematic definition of wetlands as “terrains where the nature of soil development and the communities of animals and plants thriving in it and on its surface are determined by the saturation level of water”. The USEPA [11] stated wetlands as “those lands that are immersed with ground or surface water at an adequate recurrence and span to support prevalent vegetation generally suitable to live in saturated soil environment under normal circumstances. Wetlands typically include bogs, marshes, swamps, and related areas.” Wetlands are occasionally located in brackish, freshwater, and saline environments, within abandoned ditches, estuaries, lakes, and rivers, on slopes where water erupts from the ground as a seep or spring, stream channels, and other similar areas.

Wetlands are the territories where the water table is at, or near, the ground surface and gravel and rocks are inundated in water sporadically or the whole growing season. Water tolerant plant species, known as hydrophytes, are accustomed to flourish in the hydric region of wetlands. Naturally, wetlands occur in our environment, but they can also be established to prompt the functions and operations of natural wetlands. Natural wetlands are defined as transitional regions that occur amid aquatic and terrestrial ecosystems [12].

2.1. Classification of Wetlands

Wetlands have been classified as water reservoirs that are perennial and are constructed by underground water sources or potential rainfall [13]. Therefore, wetlands are boggy lands filled with stagnant or flowing fresh or saline water representing arable lands, boggy areas, flood plains, lagoons, plains, ponds, and water storage areas. Natural wetlands consist of bogs, lakes, marshes, rivers, streams, and swamps; whereas, anthropogenic wetlands comprise canals, fish farms, paddy fields, ponds, etc. These wetlands blanket approximately 6% of the earth’s surface area, and exist in almost every state, from tropical regions to tundra [14].

According to Kadlec and Knight [15], the hydrologic conditions of wetlands are a significant factor that determine the biodiversity, geomorphology, habitat quality, and water quality. The EPA categorized wetlands into four common types in the US, i.e., bogs, fens, marshes, and swamps [16]. The aforementioned types are described as:

Marshes are frequently saturated with water, providing optimum conditions for the growth of herbaceous plants. Based on their location, they are further categorized into tidal marshes that exist near coastlines and are affected by tides and seldom by freshwater from rivers and runoff. Meanwhile, herbaceous species dominate the non-tidal marshes situated in poorly drained depressions and shallow water regions near the edges of various lakes and rivers.

Swamps contain stagnant water, and are covered with shrubs and woody trees. They occur in both freshwater and saltwater floodplains and are distinguished for having wet soil conditions during the growing season and stagnant water at specific times annually. Depending upon the vegetation type, they are termed as forested, mangrove, and shrub. Forested swamps receive freshwater from neighboring streams and rivers. Mangrove swamps are found along with the coastal areas and are identified for salt-tolerant shrubs and trees that grow in brackish to saline waters. Whereas, shrub swamps are related to forested swamps but are dominated by shrubby plants, such as buttonbush and swamp rose.

Bogs accommodate freshwater blanketed with spongy peat deposits and sphagnum moss, along with growing shrubs and evergreen trees. They hold acidic water with low nutrient levels and therefore are not suited for proper plant growth. Bogs are classified as northern bogs and pocosins, based on their location.

Fens are peat composing wetlands that are periodically fed with groundwater. They have high a nutrient content and are less acidic than bogs. Larger communities of animals and plants, such as grasses, sedges, and wildflowers, dominate these wetlands.

2.2. Functions of Wetlands

Wetlands are valuable for supporting habitats for both aquatic and terrestrial animals and plants, as well as providing nests for migrating bird species. They absorb and slow down floodwaters and hence keep flooding in check. They are also utilized for recreation purposes, such as bird watching, canoeing, fishing, and hiking. Wetland systems are employed in wastewater treatment, as they can absorb nutrients, pollutants, and sediments. Wetlands can be established to provide the above-mentioned benefits; for example, constructed aquaculture wetlands, constructed flood control wetlands, constructed habitat wetlands, and constructed wastewater treatment wetlands [12]. Constructed wetlands are manufactured for optimum performance for a specific operation, therefore, these wetlands are much more dynamic than natural wetlands.

Wetlands also sequester carbon and contain the maximum C density among various terrestrial ecosystems due to elevated organic matter deposition and decreased rates of decomposition. Even though wetlands emit about 40 percent of the total global methane, soil C in wetland systems is still acknowledged as the substantial constituent of global C budgets. It is noted that terrestrial environments, along with wetlands, can sequester up to 5 to 10 Gt C yr^{-1}, which is about 2 Gt C yr^{-1} at present [17]. Wetlands are not only garnering attention for attenuating contaminants and conserving biodiversity, but are also protected for their increased potential to sequester C beyond the present levels.

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