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Application of Constructed Wetlands for the Nitrogen Removal

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Nitrogen was a main contaminant of surface water in China presently. For instance, discharges of oil refining, chemical fertilizer, food and cultivation industry production have high concentration ammonia nitrogen in China, and the concentration of ammonia nitrogen is 200-6000 mg/L [1]. Uncontrolled discharge of nitrogen into natural water channels stimulates eutrophication of surface waters, such as lakes and rivers [1,2]. Thus, contamination of water bodies by nitrogen has led to increasing attention focused on wastewater treatment. As well, Nitrogen removal urgently needed to be solved as one of the difficult problem in the current wastewater treatment. At present, more and more researchers focused on simple and low-cost natural technologies (e.g constructed wetlands). As typical natural and environmental friendly systems [3,4] constructed wetlands primarily depend on naturally occurring energies such as solar radiation, and biomass storage, and using rooted water tolerant plants and media to provide treatment of wastewater [5,6]. As a green treatment technology and engineering measure, they have the unique advantage of producing higher effluent quality without the input of fossil energy thereby reducing operation costs and high costs of the maintenance [7-10]. Constructed wetlands are engineered wetlands with saturated or unsaturated substrates, a large biomass of plants, such as emergent, floating and submergent, and a large variety of microbial communities, like the as nitrifying bacteria denitrifying bacteria [6]. Compare with conventional technologies (such as membrane bioreactors), constructed wetlands have higher nitrogen removal efficiency and lower organic removal by increasing the contact time between wastewater and biofilms [11,12]. Besides, the characteristics of constructed wetlands are impacting resistance, stabilizing the effluent quality, simplifying operation and maintenance, and low operating cost. However, their floor spaces are larger, and the wetlands exhibit higher pollutant removal rates under greater loadings conditions [1]. In extremely cold areas, the phenomenon is more significant. The wastewater treatment technology of constructed wetlands is increasable widely used in urban and rural areas of South China [13-16]. However, constructed wetlands were not widespread uses of technology in China which spans 49 latitudes, resulting in the large differences in climate, terrain and plant communities between South and North China, especially low temperature under winter cold climate condition, such as in Northeast China. Hence, there are a lot of difficulties in adopting constructed wetlands in Northeast China.

Nitrogen was mainly removed by media adsorption, plant uptake and microbial activities in constructed wetland systems. Porous media provides attachment surfaces for plants and microbial communities and ingredients for bio-reactions as well as removing nitrogen by sedimentation, filtration and adsorption of media. However, porous media can not provide long-term stable the capacity of nitrogen removal due to their saturated adsorption, resulting in releasing nitrogen from media. Besides, nitrogen removal was no obvious by plant uptake with the low absorbing capacity [17]. As well, most plants are dormant and wilting during the cold winter in Northeast China, and have no capacity for absorbing nitrogen, which lead to reduce the nitrogen mitigation capacity of constructed wetlands. Most studies reported that nitrification and denitrification of microbes was a mainly method of nitrogen removal in constructed wetlands [18-21]. Temperature and dissolved oxygen (DO) play an important role in nitrification and denitrification of microbes in constructed wetlands [22]. Too high or low temperatures will restrain nitrification and denitrification of microbes [6,21,23,24]. The optimum temperature of nitrification and denitrification are 20-25°C, and there were hardly nitrogen removal at about 6°C, though construction wetlands were normally run during harsh winter (-25°C), the temperature occurred by accident and was not long-term [25,26]. The wetlands did not easily operated in Northeast China due to lower temperature (< -30°C) [27]. Even if the temperature of construction wetlands is improved by isolation measures, the values of the temperature are still very low (0-5°C) [28]. In winter there is great dusty permafrost in Northeast China. Permafrost forms easily in the surface of construction wetlands under low temperature, which results in restricting nitrogen removal. Xiang et al. (2009) found that wetland systems freezes and blocks easily as well as water conduit system and water outlet under winter running conditions, leading to poor drainage [29]. In addition, plants have no ability of transporting oxygen because of dried-up plant tissues in winter in the areas. Hence, some researchers thought that construction wetlands do not suit to apply in Northeast China in winter due to longer frozen (>125 d) [30]. However, we think that reformatory constructed wetlands would be used in Northeast China during the winter.

Carbon source is not only in favour of microbial denitrification but also use the carbonaceous material to synthesis their cells, while amount of carbon decrease under low temperature due to the high removal rate of biochemical oxygen demand (BOD) [31,32]. In order to increase the denitrification rate, sufficient carbon source should be added in the period, and the wetlands should be operated with the intermittent strategy so as to improve the capacity of oxygen transfer and increase amount of dissolved oxygen (DO) in the system [33,34]. Artificial aeration should not be overlooked as well. However, the increase of DO can enhance the nitrification reaction rate and the growth rate of the nitrifying bacteria, but inhibit the denitrifying bacteria activities, which go against nitrogen removal. Thus, a certain quantity of DO is necessary. Screening microbes which have the ability of nitrification and de nitrification can live by making full use of nitrogen under low temperature in winter [35]. Strengthening isolation measures of construction wetlands attracts researchers' attention so as to expand the range of their application, especially in extremely cold areas, such as a small greenhouse, plastic mulching and insulation materials. Nivala et al. [36] found that upon the installation of a pretreatment chamber and a aeration system, treatment efficiencies of the constructed wetlands dramatically improved at the Jones County Municipal Landfill near Anamosa, Iowa in winder. Under the same permafrost condition, the depth of constructed wetlands increase in order to insulate the cold air, and hydraulic retention time (HRT) are prolonged by adjusting the flow velocity of influent and effluent. Christos et al. [37] found

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that HRT were about 6d in winter when constructed wetlands have high ability of pollutant removal. However, the studies of constructed wetlands are still in a preliminary stage in the cold area of China, especially in Northeast China. As a result, there are some shortages on optimization measures of the wetland systems, such as the sources and using conditions of insulation material, appropriate HRT, and the suitable habitat of microbes due to the differences of climate and regions.

Hence, people should adjust measures to local conditions and comprehensive evaluation for constructed wetlands, especially in extremely cold areas. And we should cut down the treatment difficulties and cost of the wastewater of high initial nutrient concentrations, and combine other treatment technologies in the areas, such as biological chemical water treatment. Both physicochemical and biological methods should be used for nitrogen removal in constructed wetlands. It is necessary to study hybrid constructed wetlands with some different types in Northeast China.

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