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Design and monitoring of horizontal subsurface-flow constructed wetlands for treating nursery leachates

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ABSTRACT

Nursery leachates usually contain high concentrations of nitrates, phosphorus and potassium, so discharging them into the environment often causes pollution. Single-stage or two-stage horizontal subsurface flow constructed wetlands (HSSCW) filled with different substrates were designed to evaluate the effect and evolution over time of the removal of nitrogen and other nutrients contained in nursery leachates. The addition of sodium acetate to achieve a C:NO_3^-–N ratio of 3:1 was sufficient to reach complete denitrification in all HSSCW. The removal rate of nitrate was high throughout the operation period (over 98%). Nevertheless, the removal rate of ammonium decreased about halfway through the operation. Removal of the COD was enhanced by the use of two-stage HSSCW. In general, the substrates and the number of stages of the wetlands did not affect the removal of nitrogen, total phosphorus and potassium.

1. Introduction

Nitrate pollution of soil and surface and underground water is mainly associated with agricultural and livestock activities and, in some areas, with specific industrial activity (Fernández-Nava et al., 2008). In the case of agricultural crops, the production areas are considered as sites of diffuse subsoil nitrate pollution due to the intensive use of fertilizers. The leachates produced in soilless crops are characterized by high levels of nitrates, phosphorus and potassium and very low levels or absence of organic matter or dissolved organic carbon (Huett et al., 2005; Vymazal, 2009). The composition is also affected by the climate, making it an effluent with highly variable ion content in comparison with other effluents (Seo et al., 2008). The greatest impact of the nutrients in leachates from nurseries and greenhouses is that they accelerate eutrophication of the aquatic ecosystem (Taylor et al., 2006). Many cultural practices, such as improving the efficiency of irrigation and managing fertilizers and pesticides, have been adopted by nursery growers to limit the loss of nutrients and pesticides through leachates. Where these practices are not fully effective, many growers choose to use storage ponds to store and recycle water and thereby reduce the leachate volume and the nutrient and sediment load (Mangiafico et al., 2008). Another way of preventing environmental pollution due to leachate dumping is to treat the leachates. Different technologies exist for eliminating NO_3^- from effluent or contaminated water, such as ion-exchange systems, reverse osmosis, electrodialysis and biological denitrification (Fernández-Nava et al., 2008; Rittmann and Huck, 1989). Of the different technologies developed to remove NO_3^- from contaminated effluent, biological treatment is preferred due to its simplicity, selectiveness and low cost (Lin et al., 2008). Constructed wetlands (CW) have been shown to be an effective alternative to conventional technology in treating water with a high NO_3^- content, such as water from polluted aquifers, nitrified effluent or recirculated irrigation water (Baker, 1998). Nursery leachates, in addition to NO_3^-, also contain phosphorus and potassium. These nutrients are removed in CW by precipitation and absorption by the substrate, and incorporation into the biofilm and into the plants that grow in the wetlands (Brix et al., 2001). The predominant process in CW, specifically in horizontal subsurface flow CW (HSSCW) that are used to treat nursery leachates with a high NO_3^- content, is denitrification (Baker, 1998). This process consists of disassimilative nitrate reduction by means of heterotrophic bacteria, which use NO_3^- as an electron receiver in anaerobic or anoxic conditions, and an organic substrate as an electron donor (glucose, sodium acetate, methanol, starch or plant matter) (Sirivedhin and Gray, 2006; Wu et al., 2009). Heterotrophic denitrification is the best-known method and is considered to be more efficient than autotrophic denitrification, provided that there is a freely available source of carbon, so that the NO_3^- follows the sequence shown below to become N_2 gas (Fernández-Nava et al., 2008; Park et al., 2008):

$$NO_3^- \rightarrow NO_2^- \rightarrow NO\,(g) \rightarrow N_2O\,(g) \rightarrow N_2\,(g)$$

According to Sirivedhin and Gray (2006), the main factors affecting the denitrification rate in CW are hydraulic conditions (depth and mixing), the microbe community installed, concentration of NO_3^- and the quantity and quality of the carbon source used.

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