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Potential denitrification in wetland sediments with different plant species detritus

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Abstract

The effect of detritus originating from different plant species on denitrifying capacity was investigated in a Swedish wastewater treatment wetland. Intact sediment cores containing sediment with a detritus layer were collected from wetland basins dominated by *Typha latifolia*, *Phragmites australis*, or *Elodea canadensis* in November 2000 and potential denitrification was measured using the acetylene-inhibition method.

The cores from stands of *E. canadensis* showed more than three times higher denitrification capacity than the cores of the other plants. Bacterial abundance per unit dry weight was both highest and lowest in the detritus of *P. australis*, whereas the C/N ratio was lower in the cores of *E. canadensis*. This suggests that the submerged plant provided more organic material of high quality to support heterotrophic organisms. It is also possible that the surfaces of *E. canadensis* offered more or more suitable surfaces for bacterial growth and thereby increased the bacterial population.

It is apparent that denitrifying bacteria were more favored by *E. canadensis* detritus than by detritus from the emergent plant species at the time of sampling. Since the turnover of plant detritus varies considerably among species, the seasonal variation in denitrification capacity is likely to be quite different for different plants.

Keywords: Constructed wetland; Potential denitrification; Detritus; Macrophytes; Cold climate

1. Introduction

Treatment wetlands are frequently used to remove nitrogen from wastewater. The nitrate removal capacity varies among treatment wetlands and is difficult to predict. Nitrate removal in wetlands occurs primarily through denitrification (Brinson et al., 1984; Reddy and Patrick, 1984; Bachand and Horne, 2000), which can be promoted or inhibited in numerous ways. Studies have shown that nitrate levels are reduced more efficiently in wetlands containing plants than in unplanted wetlands (Zhu and Sikora, 1995; Lin et al., 2002). Plants play many different roles within a wetland, but the interaction between various effects of the plants on denitrification is not yet fully understood.

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In wetlands, the organic carbon is supplied mainly by the vegetation and it is used as a carbon and energy source for heterotrophic bacteria, such as the denitrifying bacteria. Accordingly, the availability of easily decomposable plant material can be a factor limiting denitrification in wetland systems (Ingersoll and Baker, 1998; Kozub and Liehr, 1999; Lin et al., 2002). Ingersoll and Baker (1998) studied wetland microcosms and found that addition of dried stems and leaves of *Typha* spp. resulted in increased nitrate removal. Kozub and Liehr (1999) also performed experiments on wetland microcosms, and they observed that adding acetate as an external carbon source led to substantially increased denitrification rates. Furthermore, supplying organic carbon raises the heterotrophic activity, which indirectly favors denitrification by lowering oxygen concentrations (Nielsen et al., 1990).

Plant tissue also provides a large amount of surface area for microbial growth. Bacteria are much more abundant when grown attached to surfaces than when suspended in water (Hamilton, 1987). Commonly, the sediment is considered to be the site where the predominant denitrification occurs in wetlands (Seitzinger, 1988). Later studies have shown that denitrification in periphytic communities on submerged plants can make a significant contribution to overall denitrification in a wetland (Eriksson and Weisner, 1997; Toet, 2003). In addition, it has been observed that old decaying twigs constitute suitable growth sites for denitrifying bacteria (Bastviken et al., 2003; Toet, 2003). In contrast, plants can also play a role in reducing denitrification in wetlands. Submerged plants increase the oxygen concentrations in the water through their photosynthesis, and thus create conditions that are less favorable for denitrification.

The net effect of vegetation depends on the characteristics of the plants, such as the plant species, the growth rate and the total biomass of the plants. Different plant species supply the denitrifying bacteria with organic carbon of divergent quantity and quality. They also provide surfaces that can be more or less suitable for bacterial attachment, and they differ regarding their potential to oxygenate the water. Large-scale experiments show that the nitrate removal vary between wetlands containing different plant species (Bachand and Horne, 2000). Bachand and Horne (2000) noted a higher nitrate removal rate in wetlands containing mixed stands of emergent macrophytes, grasses, *Lemna* spp. and algae than in those containing monocultures of *Scirpus* spp. or *Typha* spp. In a study by Lin et al. (2002), they observed that wetland cells (0.24 m^2) planted with *Penniserum purpureum* (emergent) consistently removed more nitrate than those planted with *Phragmites australis*, *Commelina communis* (emergent), *Ipomoea aquatica* (free-floating) or *Pistia stratiotes* (free-floating). Zhu and Sikora (1995) investigated small cells (0.14 m^2) and noted more substantial removal of nitrate in the presence of *Phragmites communis* or *Phalaris arundinacea* than with *Typha latifolia* or *Scirpus atrovirens georgianus*. In the cited studies, mass balance calculations were performed to determine nitrate removal. These calculations indicated that denitrification was the main mechanism for nitrate removal, and the authors suggested that denitrification was limited by available organic carbon. This further suggests that plants have significant species-specific effects on denitrification capacity in wetlands. However, the quantitative importance of those different effects of plants on wetland denitrification remains to be evaluated.

In the present study, we investigated the effect of detritus originating from different plant species on denitrification in a constructed wetland system, and we also examined the extent to which the denitrification capacity was correlated with the detritus C/N ratio and bacterial abundance. We compared the denitrifying capacity of wetland sediments containing detritus of *T. latifolia*, *P. australis* and the submerged plant *Elodea canadensis*, and denitrification was measured using the acetylene-inhibition method in intact sediment cores. To be able to focus on the effects of the detritus, we incubated the cores under conditions that were not limited by nutrients or oxygen concentrations, and all other factors that might have influenced the outcome were kept equal for all treatments.

2. Methods

2.1. Study site

The study was performed in a pilot-scale free water surface wetland system at the Nykvarn wastewater treatment plant in Linköping, Sweden. The wetland was established in 1993 and used from 1993 to 2000 to treat partly nitrified wastewater. The wetland was con-