ABSTRACT

Wetland systems are emerging technologies for sustainability, through the retention and transformation of nutrients and with a potential for recycling. Vertical flow wetland systems were developed to provide an improved hydraulic regime and nutrient removal. The aim is the development of compact wetland systems for a wide range of applications.

Laboratory-scale batch loaded bucket systems were planted with *Phragmites australis* and filled with sand. 83% and 90% removal efficiency was provided for total-N and total-P, respectively.

For more detailed studies of removal mechanisms, upflow column systems with sampling ports were planted with *P. australis* and filled with sand. Nitrogen and oxygen concentration gradients showed that plant uptake, rather than denitrification, was the main N removal mechanism. The proposed mechanism was an interaction between root uptake/nitrification where root uptake of oxygen-demanding ammonia delays the onset of oxygen free conditions and promotes additional nitrification. This capacity opens the possibility of nitrogen retention and recycling in constructed vertical flow wetlands.

The importance of rhizome accumulation was studied for agricultural river water in column systems. Nitrogen was effectively accumulated in the rhizomes (48% of influent mass), while phosphorus accumulation (approximately 3% of influent mass) was less satisfactory. The main design factor for nitrate was detention time based on target concentration removal. For ammonia, initial concentration should be controlled carefully to achieve an optimum uptake. P removal efficiency in vertical column systems increased through effluent recirculation with increasing flow rate, which also enhanced substrate adsorption. Hydraulic loading showed an effect on P removal. Intermittent loading with long resting intervals resulted in lower effluent concentrations, although higher mass removal was achieved when P was introduced continuously.

Based on small-scale performance, a vertical flow pilot-scale system was constructed for ammonia removal from oil refinery effluents. Plant growth and establishment of a critical root density are long term processes which need to be accounted for in scaled-up systems.

A full-scale upflow system in Piracicaba, Brazil, designed for primary settled wastewater treatment, was studied for the removal of nitrogen and phosphorus. The fine grained soil layer placed on the gravel layers was responsible for high P removal of the wetland (> 90%). Ammonia and nitrate removal was 50% and 78% respectively. Brazilian upflow wetland systems are commonly planted with rice and recycling of nutrients has been applied.

The present study on the capacity and mechanisms of the vertical flow wetland system shows that this is a promising technology for the removal and recycling of nutrients.

*Key words:* Agricultural runoff, constructed wetland, nutrient removal, nutrient recirculation, *Phragmites australis*, rhizome accumulation, vertical upflow system.