



In situ denitrification and DNRA rates in soils and underlying groundwater of an integrated constructed wetland

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Nitrogen (N) removal efficiency in constructed wetlands (CW) is low and again it does not in itself explain whether the removed N species are reactive or benign. Evaluation of environmental benefits of CW necessitates knowing N removal mechanisms and the fate of the removed N in such system. In situ denitrification and DNRA (dissimilatory nitrate reduction to ammonium) rates were measured in an earthen lined 5-cell integrated CW using ^{15}N -enriched nitrate ($\text{NO}_3\text{-N}$) push-pull method. Measurements were conducted in 2 groundwater depths (shallow- soils in CW bed; and deep- 4 m below CW soils) in 2 contrasting cells (high vs. low nutrient loads) of the CW. Denitrification ($\text{N}_2\text{O-N} + \text{N}_2\text{-N}$) and DNRA were the major $\text{NO}_3\text{-N}$ removal processes accounting together for 54-79% of the total biochemical removal of the applied $\text{NO}_3\text{-N}$. Of which 14-17 and 40-68% were removed by denitrification and DNRA, respectively. Both the processes significantly differed with CW cells indicating that N transformations depend on the rate of nutrient loads in different cells. They were significantly higher in shallow than deep groundwater. Environmental conditions were favourable for both the processes (i.e. low dissolved oxygen and low redox potential, high dissolved organic carbon, high total carbon and high dissolved organic N) but DNRA rate was favoured over denitrification by high ambient NH_4^+ concentrations, reduced sulphide and low pH (5.9 - 7.0). Low pH might have limited denitrification to some extent to an incomplete state, being evident by a high $\text{N}_2\text{O-N}/(\text{N}_2\text{O-N} + \text{N}_2\text{-N})$ ratio (0.35 ± 0.17 , SE). Relatively higher $\text{N}_2\text{O-N}/(\text{N}_2\text{O-N} + \text{N}_2\text{-N})$ ratio and higher DNRA rate over denitrification suggest that the end products of N transformations are reactive. This N_2O can be consumed to N_2 and/or emit to atmosphere directly and indirectly. The DNRA rate and accumulation of NH_4^+ indicated that CW is a net source of NH_4^+ in groundwater. Ammonium produced by DNRA can be fixed in soils and, when exchange sites are saturated, can flow to ground and surface waters. These results suggest that conventional input – output balance for N removal is misleading unless the removal mechanisms are fully understood and the fate of the removed N are known.