# Impact of Hydraulic Residence on $SO_4^{2-}$ and $NO_3^-$ Reduction Dynamics in Woodchip Bioreactors Supporting a Unit Process Open Water Wetland

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Unit Process Open Water (UPOW) wetlands are shallow engineered wetlands that have been naturally colonized by a photosynthetic, benthic biological mat which enables robust attenuation of nitrate, pathogens and trace organics. With an increased interest in using this passive treatment technology to treat other impaired waters, we propose further advantages of hybrid / additive technologies as part of engineered wetland design. The purpose of this study was to evaluate the impact of Empty Bed Contact Time (EBCT) and $SO_4^{2-}$ concentrations on the attenuation of $NO_3^-$ in a woodchip bioreactor that can be used in conjunction with a UPOW wetland. Three EBCT variations were analyzed using ten upflow columns with a mixed woodchip/alfalfa substrate, an analogue impaired water with 15 mg/L $NO_3^-$—N and a range of environmentally relevant $SO_4^{2-}$ concentrations (0 mg/L to 1000 mg/L). The study suggests that a woodchip bioreactor's ability to decrease the surface area of a UPOW wetland through the management/design of bioreactor EBCT is based on the desired outcomes for the technology. With a 12 hour EBCT, the $NO_3^-$ removal rate was not substantially different across $SO_4^{2-}$ concentrations nor were soluble sulfides detected in any column effluents. In EBCTs greater than 48 hours, $NO_3^-$ was attenuated below detectable limits and, in columns where $SO_4^{2-}$ concentrations were above 100 mg/L, soluble sulfide was detected in the effluent. It appears that shorter EBCTs may support decreasing wetland surface area through increasing $NO_3^-$ removal while limiting the potential for sulfide production. Conversely, the study suggests that a focus on sulfate attenuation or metal(loid) removal coupled to biogenic sulfide genration would require longer EBCTs that may result in increased wetland surface area requirements.