

Technical note

A simple tool to help decision making in infrastructure planning and management of phytotreatment ponds for the treatment of nitrogen-rich water

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Abstract

In situ experimental studies were carried out aimed at the quantitative estimation of biological processes involved in nitrogen removal such as macro-algal assimilation and bacterial denitrification and their optimisation in two experimental phytotreatment ponds colonised by the macro-algae *Ulva rigida* in central Italy. Results from an *in situ* manipulative experiment estimate that *Ulva* carrying capacity defined as the macro-algal biomass in which the uptake of dissolved inorganic carbon (DIC) equals the production of oxygen (O₂), was close to 300g·m⁻² dry biomass (dw). At this carrying capacity the experimental assessment of *Ulva* growth rates and *Ulva* assimilation rates and their optimisation with use of a logistic model estimated that maximum inorganic nitrogen removal (~0.04 mol N·d⁻¹·m⁻²) was attained when *Ulva* biomass reached 150 g_{dw}·m⁻² and growth rate was 0.1·d⁻¹. Denitrification rates accounted for a small amount of total nitrogen removal (~150 μmol N·m⁻²·h⁻¹) although an intact core incubation experiment demonstrated that denitrification increased with increasing nitrate concentrations. Based on experimental results a series of calculations have been made by use of MATLAB algorithms to facilitate manipulation of easy-to-measure variables (infrastructural, chemical and biological) and subsequent gross estimates of their effect on biological nitrogen removal efficiency, thus providing a simple tool to help decision making for infrastructure planning and management of phytotreatment ponds.

Keywords: aquaculture wastewater, phytotreatment pond, *Ulva rigida*

Introduction

Phytotreatment ponds with foliose macro-algae are widely employed for the treatment of ammonia-rich water due to their simple arrangement (not needing complex infrastructure) and low cost (Redding et al., 1997; Brix, 1999; Tanner, 2001; Vymazal et al., 2001; Lin et al., 2002; Schulz et al., 2003). In terms of Italian Government law, the construction of phytotreatment ponds is compulsory for wastewater treatment under particular circumstances and various activities, the main being land-based aquaculture. The aim of phytoremediation ponds is the removal of dissolved nitrogen from wastewater to be safely discharged into the natural environment. Foliose macro-algae are primarily utilised for this purpose and *Ulva rigida* is one of the most common due to its high net growth rates, nitrogen uptake capacity and resistance to environmental stress (Laliberté et al., 1994). Coupled to dissolved nitrogen assimilation by primary producers, removal of particulate matter must be previously achieved via sedimentation pond in order to fully exploit macro-algae assimilation (Bartoli et al., 2005) and prevent deterioration of microbiological quality of the treated water (Vezzulli et al., 2005). Despite the potential usefulness of sedimentation/phy-

totreatment pond system for the treatment of nitrogen rich water one of the main reasons limiting their full exploitation is the lack of suitable methods to help decision making in pond infrastructure planning and pond management. Failing to observe these rules limits the usefulness of the pond and may lead (e.g. due to macro-algal collapse in an un-managed pond) to further deterioration of the wastewater. Therefore, the functionality of phytoremediation ponds is based on structural variables to be planned before construction (pond area, depth and water flow) and biological and chemical variables (macro-algae biomass, dissolved ammonia and nitrate concentrations in inlet water) to be experimentally estimated in order to optimise biological nitrogen removal (macro-algal assimilation and denitrification) through a correct management. Both of these variables are strongly correlated and estimation of their values and optimal setting requires expensive investigation often resulting economically unaffordable for the end-users. To provide a solution to this problem we developed a user-friendly tool able to facilitate manipulation of these variables (structural, chemical and biological) and provide subsequent gross estimates of their effect on biological nitrogen removal efficiency, thus providing a tool to help decision making for planning and management of phytotreatment ponds. The tool is based on a series of experimental studies aimed at the quantitative estimation of biological processes involved in nitrogen removal such as macro-algal assimilation and bacterial denitrification and their optimisation as a function of structural and chemical pond variables. The setting-up of the tool has been carried out during late spring (May

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