Research Application Summary

# Nitrogen dynamics and removal by algal turf scrubber under high ammonia and organic matter loading in a recirculating aquaculture system

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**Abstract**

High total ammonia nitrogen (TAN) concentrations were introduced to an Algal Turf Scrubber developed under loadings of *Clarius gariepinus* recirculating aquaculture system effluent to determine its potential and dynamics of TAN removal. TAN removal rates were not affected at total suspended solids concentration of up to 0.04g TSS/l ($P > 0.05$). TAN removal rates 0.93-0.99g TAN/m²/d were recorded at loading rates between 3.76 and 3.81 g TAN/m²/d. TAN removal exhibited ½ order kinetics between 1.6 to 2.3mg/l TAN concentrations. TAN removal increased with TAN loading and hydraulic surface loading. In addition, TAN removal was higher than in fluidized bed and trickling filters.

Key words: Aquatic plants, *Clarius gariepinus*, effluent discharge, waste water treatment

**Résumé**

Des concentrations élevées en azote d'ammoniaque total (TAN) ont été introduites à un épurateur de gazon d'algues développé sous des chargements de *Clarius gariepinus* recyclant l'effluent de système d'aquiculture pour déterminer son potentiel et dynamique de la suppression du TAN. Des taux d'élimination du TAN n'ont pas été affectés à la concentration des solides totaux suspendus jusqu'à 0.04g TSS/l ($P > 0.05$). Les taux de suppression du TAN 0.93-0.99g TAN/m²/d ont été enregistrés aux taux de chargement situés entre 3.76 et 3.81g TAN/m ² /d. Le déplacement duTAN a montré la cinétique d'ordre de ½ entre 1.6 et 2.3mg/l des concentrations de TAN. Le déplacement de TAN a augmenté avec le chargementde de TAN et le chargement de surface hydraulique. En outre, le déplacement du TAN était plus haut que dans le lit fluidisé et les filtres d'écoulement.

Mots clés: Plantes aquatiquess, *Clarius gariepinus*, decharge de l'effluent, traitement des eaux usées

## Background

One of the major water quality related problems reported from aquaculture is effluent discharge with high concentrations of nitrogen (N) and phosphorus (P) (Smith, 2003). Currently, use of aquatic plants/algae, which are more environmental friendly, in waste water treatment is drawing considerable attention. Periphyton has demonstrated ability to improve water quality in a Recirculation Aquaculture System (RAS). A periphyton reactor can replace a trickling filter and a sedimentation unit in a RAS processing feed load of up to 32g/m²/day (Sereti *et al*., 2005). The present study aimed at estimating potential TAN removal in an ATS grown under varying ammonia loadings.

## Literature Summary

The primary goal of biofiltration is to remove ammonia ($NH^{+}_{4}$-N and $NH_3$-N) and nitrite ($NO_2$). $NH_3$-N is highly toxic un-ionized form. Nitrate ($NO_3$) is the least harmful form of inorganic N (Parent and Morin, 2000). Ammonia uptake rates can be measured under light and dark conditions (Verdegem *et al*., 2005). In waste water treatment, reported nutrient removal capacity of periphyton either by itself (Davis *et al*., 1990) or in combination with emergent floating or submerged macrophytes (Brix and Schierup, 1989; Korner *et al*., 2003; Toet, *et al*., 2003) varied, declining with extremely increased areal loading rate, decreasing periphyton surface to water volume ratio and increasing depth.

## Study Description

The study was conducted in the hatchery "De Haar Vissen" at Wageningen University, The Netherlands. The periphyton RAS consisted of fish tank, periphyton reactor and a sump (Fig. 1). Effluent water (Q) from catfish tanks was diverted into a collector tank where it was homogenized by stirring before

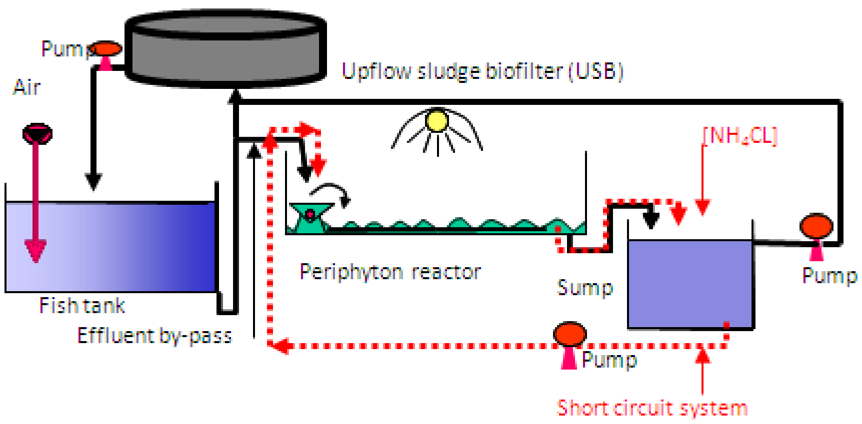


**Figure 1. Schematic overview of the experimental set-up.**

passing to the ATS. The ATS was illuminated by two halide lamps.

The ATS was operated under different flow rates to change the organic matter load to the ATS. The experiment lasted 5 weeks. On the seventh day of each week, a short circuit was introduced in the system. The periphyton reactor was disconnected from the RAS, and operated in short circuit continuously re-using sump water, for maximum of 12 hrs under continuous light condition. Prior to the start the sump was emptied. The overflow pipes from the collecting bucket to sump and from sump to the main effluent pipe were disconnected. At the start of the circuit, the water in the sump was treated with dissolved Ammonium Chloride ($NH_4Cl$) to attain 3.11mg/l, 5.13mg/l or 8mg $NH_4$-N /l in the water, respectively.

The first water sample was collected at the inlet immediately after dissolving the $NH_4CL$ into the sump whereas subsequent samples were collected every 20-30 minutes in 10ml tubes for daily analysis of $NH_4$, $NO_3$, and $NO_2$ using a SAN auto-analyzer (Skalar, The Netherlands), and in 500-ml prior to the short circuit for total suspended solids (TSS) and dry matter (DM) analysis (APHA, 1998). Dissolved (Mg/L), temperature (°C) and conductivity were also measured throughout each experiment. After each experiment, the periphyton screens were partially (50%) harvested to allow for quick development of the biofilm in the following week, and sludge was collected from the periphyton tank. Data were analyzed in S-Plus 6.1.

## Results

TAN removal started immediately after ammonia was dissolved into the system water. Higher zero-order removal rates were observed for higher ammonia loads. Van Rijn and Rivera (1990), Davis *et al.* (1990) and Pizarro *et al.* (2002), also reported that N removal rates increased with increasing ammonia loading rate and biomass.

Nitrite accumulated in the ATS before onset of removal which varied with loading conditions. Nitrite accumulated due to initial suboptimal balance between Nitrosomonas and Nitrobacter like organisms. When nitrification rate approached a constant rate, 2- 4 hours later, $NO_2$-N accumulation stopped.

The general decrease in nitrate concentration with time makes ATS superior to trickling filters with regards to nitrate removal. The decrease in nitrate with time offers a possibility to reduce necessity of water exchange in RAS using ATS with the goal of reducing nitrate levels. Since removal rate is higher in young biofilm than in a mature one (Valeta, 2006), complete harvesting of periphyton mat would further reduce the need for water exchange.

In conclusion, the ATS ably removed TAN at removal rates as high as 9.49 TAN/$m^2$/d under initial TAN concentration of 8g/$m^3$. The maximum half-order TAN removal (0.90g/$m^2$/d) was higher than rates recorded for most of other types of filters such as fluidized bed filters and trickling filters. The ATS removed TAN to achieve minimum concentrations which are generally lower than thresholds for species such as Tilapia. TAN removal showed ½ order kinetics between 1.6 to 2.3mg/l TAN concentrations. Regardless of increase in weekly sludge biomass accumulation in the ATS prior to ammonia loads, TAN removal rate increased with nutrient loading, which increased with hydraulic surface loading rate. TAN removal rates were not affected at total suspended solids concentration of up to 0.04g TSS/l ($P > 0.05$). An ATS is also ideal for removal of nitrate which reduces need for water exchange.

## Research Application

The application of algal turf scrubber technology in recirculating aquaculture can only be possible after thorough understanding of the potential and dynamics of aquaculture effluent is attained. In this regard, this study has provided further insight into the applicability of ATS in RAS which forms a basis for further studies into commercial application of the ATS as at present application remains at laboratory scale.

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