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AGRICULTURAL DRAINAGE TREATMENT AND NUTRIENT RECOVERY USING FILAMENTOUS ALGAE NUTRIENT SCRUBBERS

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Introduction

Filamentous Algae Nutrient Scrubbers (FANS) are a novel agricultural drainage treatment system that grows green filamentous algae to recover nutrients for beneficial reuse. Current mitigation tools for agricultural drainage treatment include surface-flow constructed wetlands, woodchip bioreactors and riparian management (Tanner and Sukias, 2011; Sutherland and Craggs 2017; Woodward et al., 2020; Rivas et al. 2020). (Figure 1.)

Figure 1: Current mitigation systems for agricultural drainage treatment: constructed wetland, at Toenepi Waikato and woodchip bioreactor at Waituna, Southland (C. Tanner).

These mitigation tools require relatively high land areas for modest nutrient removal, particularly of phosphorus. FANS have potential to be developed for New Zealand conditions to provide an additional tool for agricultural drainage treatment. The aim is to turn a symptom of the eutrophication problem - filamentous algae growth, into part of the solution.

Filamentous algal systems have been used to treat agricultural drainage in the USA, where they have also been used to treat various agricultural effluents and wastewaters (Figure 2).

Figure 2: Filamentous algal nutrient scrubber at field scale in California, USA. (Rupert Craggs)

Filamentous Algal nutrient scrubbers

FANS are gently sloping floways that are covered with attached filamentous algae. The water flows down the floway and over/between the filamentous algae (Figure 3). The water is treated through a combination of algal photosynthesis and growth (nutrient assimilation and oxygenation) and physical filtration (settling, adsorption and precipitation).

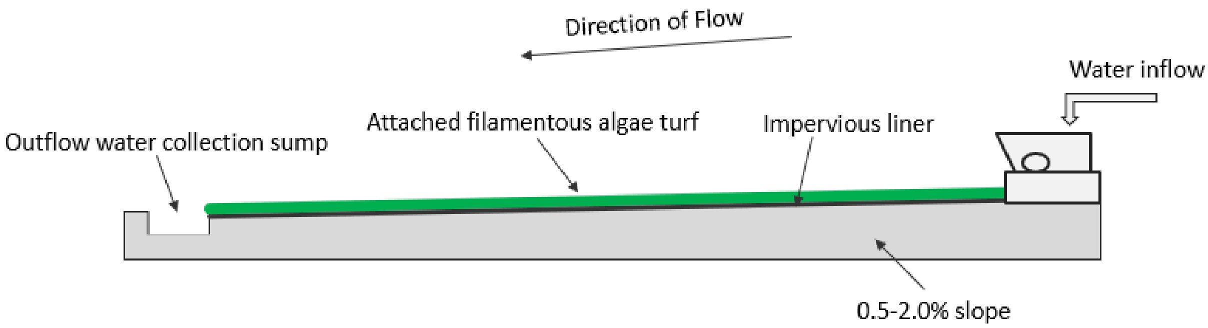

Figure 3: Cross-section of a filamentous algal nutrient scrubber. (Harizah Hariz)

Potential Benefits Compared with Constructed Wetlands

A literature review indicated that compared with constructed wetlands, FANS could have double the removal capacity of TN (FANS: 88 g m^{-2}.y; Constructed Wetlands: 40 g m^{-2}.y) and about four times the removal capacity of TP (FANS: 12 g m^{-2}.y; Constructed Wetlands: 3 g m^{-2}.y). Therefore, FANS would therefore require less land area for the same nutrient removal (half for nitrogen and quarter for phosphorus) (Sutherland and Craggs 2017). Nitrogen is assimilated into algal biomass by FANS rather than being returned to the atmosphere by wetlands. Phosphorus removal is more consistent in FANS as the algae assimilated phosphorus is regularly harvested, compared with constructed wetlands which can become saturated.

FANS will likely have similar construction costs to constructed wetlands (~$200k ha^{-1} for a 1-10 ha system), so they may have half the cost for the same nitrogen removal. FANS only take 1-3 weeks to establish algae on the floways, compared with 3-12 months that is typically required for the establishment of constructed wetland plants. The drainage water nutrients are assimilated into algal biomass at seasonally varying productivities of 5-15 g m^{-2}.d. This biomass has potential to be beneficially used as a soil amendment, animal feed (>40% protein) or higher value products.

Potential Disadvantages Compared with Constructed Wetlands

FANS require much more regular maintenance (weekly to monthly) compared with the typical annual maintenance required for wetlands. Wetlands are known to provide multiple habitat values, whereas that of FANS is unknown (possibly for wading birds). Wetland are recognised for provision of aesthetically pleasing natural space, which has yet to be tested for FANS. FANS may be more susceptible to changes in flow or nutrient loading than wetlands which have much longer Hydraulic Retention Times (HRTs) to buffer such changes. FANS biomass production and treatment performance may be dramatically reduced by biological (grazer infestation) or physical (heavy rain/hail events) disturbance.

FANS Outdoor Mesocosm Experiments

Experiments were conducted using outside mesocosm floways (6 m long × 0.12 m wide; area: 0.72 m^2) at the NIWA Ruakura Algal Research Facility, Hamilton (Figure 4). The I-beams were set at a 0.5% slope and contained a textured HDPE liner to which the filamentous algae attached. A simulated agricultural drainage water (NO_3-N: ~2 mg L^{-1}; DRP: ~0.2 mg L^{-1}) was provided to each floway at a flow of 1 L min^{-1}. Nitrate and DRP removal were measured twice weekly and algal biomass was harvested weekly. The experiment was conducted over three seasons (winter, spring and summer).

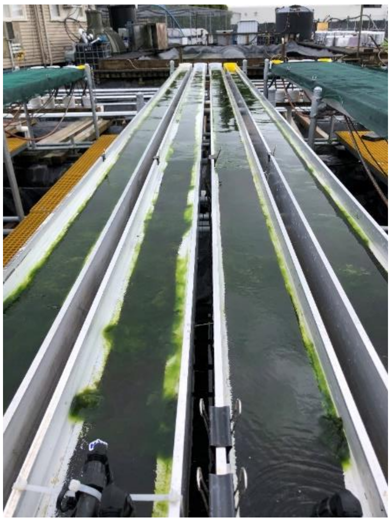

Figure 4: Filamentous algal nutrient scrubber mesocosm floways. (Jason Park)

Nutrient removal improved from winter to spring and then summer for both nitrate (Average: 0.32 g N m^{-2}.d) and DRP (Average: 0.07 g P m^{-2}.d). When the results of this outdoor mesocosm experiment are extrapolated to annual nutrient removal rates (133 g Nitrate-N m^{-2}.y and 21.5 g DRP m^{-2}.y) they are inline with removal rates obtained with systems in the USA (88 g TN m^{-2}.y and 12 g TP m^{-2}.y respectively). These nutrient removal rates are at least double those of constructed wetlands for N (40 g TN m^{-2}.y) and four times those for P (3 g m^{-2}.y) (Sutherland and Craggs 2017). Average seasonal biomass productivity varied from 0.5 g m^{-2}.d in winter to 4.6 g m^{-2}.d in summer. The FANS were dominated by four main genera of native filamentous algae (*Oedogonium* sp., *Rhizocloneum* sp., *Cladophora* sp., and *Spirogyra* sp.). The filaments were partially covered with epiphytic diatoms and filamentous cyanobacteria.

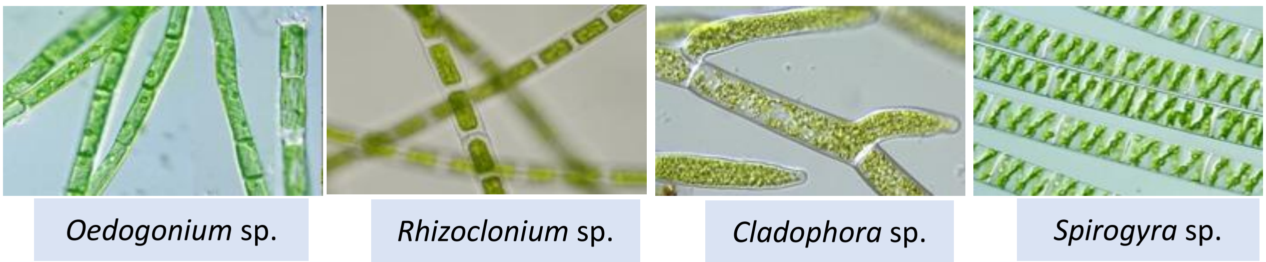

Figure 5: Dominant filamentous algae genera found on the mesocosm FANS. (Harizah Hariz)

We are currently investigating different options for FANS systems including floating systems within existing freshwater bodies (streams, rivers, lakes). Culturally acceptable beneficial reuse of the nutrients that are recovered as algal biomass are currently being with farmer and Māori end-users.

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