Potential of algae turf scrubbers (ATS™) for elimination of phosphorus from swimming ponds

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Abstract Algal Turf Scrubbers (ATS) are water treatment devices that use light and nutrients in the (waste)water to grow periphyton community; undesirable chemicals are removed by physical, chemical and biological processes. So far, most ATS systems were operated in water bodies with relatively high nutrient concentrations. Little is known about the performance of ATS under low concentration of phosphorous (P), yet there are potential applications where such conditions are met. The paper presents a series of experiments that focus on the implementation of small-scale ATS systems to eliminate P from natural swimming ponds (SP). SPs are typically subject to fluctuating P concentrations and require the maintenance of very low levels of P (< 10 μg L^{-1}) in order to prevent undesirable algal growth. ATS systems proved to be capable of maintaining such low levels, both in laboratory and field conditions.

ATS systems (Adey, 1982) were used to remove nutrients from different wastewaters, among others: agricultural run-off (Adey et al., 1993), secondary treated wastewater (Craggs, 2001) and anaerobically digested dairy manure (Pizarro et al. 2002). The reported phosphorus removal rates ranged from 0.12 – 0.73 g P m^{-2} d^{-1}. Current studies thus document the successful operation of ATS systems under nutrient-rich conditions (PO_4-P levels > 1 mg L^{-1}). The question therefore arises whether such systems can be applied for nutrient elimination down to the very low levels of PO_4-P found in open water bodies (below 10 μg L^{-1}).

Swimming Ponds (SP) are small artificial freshwater bodies providing both a natural component to the garden and an opportunity for recreational swimming. Instead of disinfection with chlorine as used in conventional swimming-pools, they contain a natural water quality which is provided by active microbial biofilms on plant roots and biofilters which maintain a regenerative capacity.

Nutrient concentrations in SP vary seasonally, depending on the weather conditions and number of users (swimmers). Natural P inputs can amount up to 1 mg P per m^2 pond surface and day. For every swimmer an additional input of 100 mg P per day can be assumed (Schulz, 1981). Phosphorus promotes algal growth, which in turn reduces visibility. Safety regulations require visibility in swimming ponds to be > 2 m. Therefore it is recommended that P concentrations in SP do not exceed 10 μg P L^{-1} (FLL, 2010).

An ATS system installed next to the pond could help to reduce P concentrations in the pond water if it would be able to assimilate P at very low levels. This question was investigated, as well as P elimination under different water flow rates and the effect of prior starvation on P uptake by algae.

The ATS system in the laboratory setup consisted of 5 modules (Figure 1). Each was built of 1.5 mm stainless chromium steel (2.0 m x 0.57 m x 0.10 m), and operated at a water depth of 50 mm. Artificial light (1000 W) was provided for 8 h d^{-1}.

A modified version of BB-Medium (Bold, 1949), omitting any components containing P, was used as P-free growth medium. P was supplemented by adding Wuxal® liquid fertiliser (Maag Agro, Dielsdorf, CH). A mix of Lake Zurich and pond water was used as inoculum. Medium was transported continuously into the tilt tray, which emptied in a short flush to the periphyton when the tilt level was reached (about 3x min^{-1}). Total algae biomass was weighed and analysed for dry weight and total phosphorus, and the water for phosphate. Oxygen, temperature, pH, and conductivity were recorded with data loggers (WTW MultiLab® P4 data logger). Total phosphorus P_{tot} was determined by spectrophotometry (Hach Lange LCK 349). Orthophosphate was measured according to Schwarzenbach (2005).

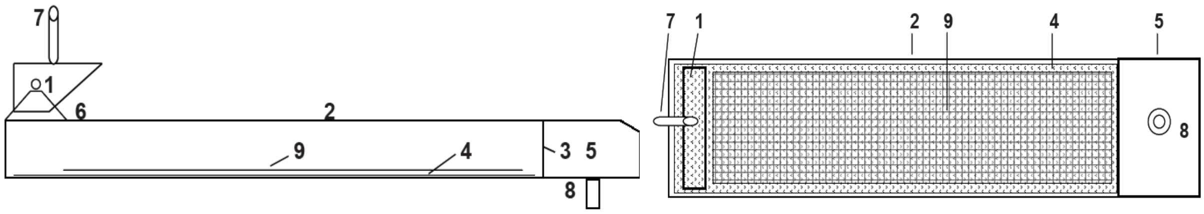

Figure 1 Algal Turf Scrubber (ATS) seen from the side (above) and from above (below). Legend: (1) tilt tray, (2) algae tank, (3) spill over rim (to 5), (4) algae turf carrier matrix (1 m^2 black PE grid, mesh size 1.8 mm, Type SEFAR Petex 07-1180/60), (5) collecting channel, (6) suspension device for tilt tray, (7) water inlet, (8) water outlet, (9) fixation grid for carrier matrices

In batch experiments, ATS were able to reduce P concentrations from 23 - 38 $\mu g\ L^{-1}$ to 5.0 - 6.3 $\mu g\ L^{-1}$ within 24h. P elimination was higher at higher flow rates of medium, the most efficient flow rate being 7.5 L min^{-1}.

Despite of a reduced algae dry mass, algae that were deprived of P for 7 days were capable to eliminate up to three times more P than well fed algae, both at day and during the night. Well-fed precondition of algae showed a significantly lower P elimination rate than starved (P=0.0153, F=8.53 on 1 and 10 DF).

The study demonstrated the capability of ATS systems to function well also at low P concentrations, and to be able to reduce P-concentrations down to 5 $\mu g\ L^{-1}$.

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