38i Use of Periphyton for Nutrient Removal from Waters

Jan Vymazal

INTRODUCTION

Many lakes and streams are showing signs of excessive fertilization due to the input of aquatic plant nutrients from anthropogenic sources. Although nitrogen and phosphorus are not the only nutrients required for algal growth, it is generally agreed they are the two main nutrients involved. Phosphorus is often found to be the key element. Eutrophication is emerging as one of the most significant causes of water quality deterioration. Eutrophication of lakes, and especially of drinking water reservoirs, leads to profound changes and has considerable detrimental effects on the quality of water.

Drinking water treatment difficulties presented by algal development in reservoirs can be prevented, first of all, by lowering nutrient input into drinking water reservoirs. One possible intervention is to use naturally growing periphyton communities on artificial substrata to lower nutrient loads in reservoir tributaries. This study evaluated the efficiency of periphyton communities in nutrient elimination in a continuous-flow trough in the field.

MATERIALS AND METHODS

The continuous-flow trough was made of wood and was 5 m long, 0.5 m wide, and 0.7 m deep. The inside walls and the bottom of the trough were laminated. Fine-mesh silon (a kind of nylon) screens (50 × 50 cm, hole size ca. 1 mm^2) were fixed in plastic frames and placed perpendicular to the direction of flow. Screens were held in place 20 cm apart by grooves on the side walls of the trough.

Vltava River water was used for all experiments in the field trough. Retention time in the trough was 4 hr, based on the results of preliminary laboratory experiments. Flow was 312.5 L/hr (total volume of water in the trough was 1250 L).

The first experiment was aimed at examining nutrient elimination with time,

periphyton community growth, and composition. Efficiency of nutrient elimination was monitored with NH_4^+, NO_2^-, NO_3^-, and PO_4^{3-} analyses. Triplicate influent and effluent samples were analyzed to determine the amount of nitrogen and phosphorus taken up in the trough, and results were expressed as elimination (E), which was determined from the relation:

$$E = \frac{C_0 - C_1}{C_0} \times 100\ (\%) \qquad (1)$$

where C_0 = influent concentration of observed chemical
C_1 = effluent concentration

Elimination was observed at two- to three-day intervals, and average values were plotted.

The algal growth potential (AGP) was determined to measure the extent of total decrease in water fertility. As the test alga, *Scenedesmus quadricauda* (Turp.) Breb., strain Greifswald/15 was used, and triplicate samples were taken for each datum plotted.

The saprobic index (S) of the periphyton community was computed using the following formula:

$$S = \frac{\Sigma S_i h_i}{\Sigma h_i} \qquad (2)$$

where S = saprobic index of the community
S_i = saprobic value of individual species
h_i = abundance of a species in the sample

with relative abundance on a scale of 1 to 5 (1 = rare, 2 = occasional, 3 = frequent, 4 = abundant, and 5 = very abundant). Samples were scraped from six sites, both in inflow and outflow parts of the trough. For calculation of the saprobic index (S), average values were used. When calculating S, only periphytic organisms were taken into account, i.e., planktonic organisms were not used for calculations in spite of their presence, which is primarily due to mechanical holding. However, planktonic organisms significantly added to the overall metabolism of the periphyton community.

Species composition of inflow and outflow communities was compared by computing Sørensen's similarity coefficients (C_S):

$$C_S = \frac{2n_{jk}}{n_j + n_k} \qquad (3)$$

where n_{jk} is the number of species occurring in both sample j and in sample k, and n_j and n_k are the numbers of species occurring in sample j and k, respectively. If there is no correspondence between two samples, then C_S = 0. If

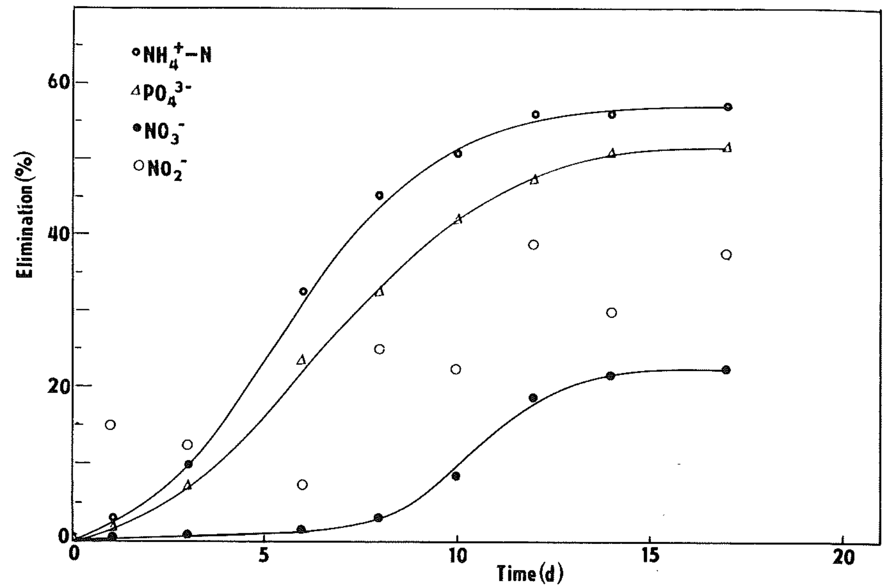

Figure 1. Elimination of nutrients during first field experiment.

there is maximal correspondence, then $C_S = 1$. Operation of the first field experiment was May 6–23, 1984.

The second experiment was aimed at the course of nutrient elimination and composition of periphyton communities in the trough. Nutrient elimination was controlled by NO_3^-, NH_4^+, and PO_4^{3-} analyses. Methods for calculation of S and C_S were similar to those used during the first experiment. The operation period was July 22 to August 15, 1984.

RESULTS

The course of nutrient elimination is given in Figures 1 and 2. The maximum values of elimination during the first field experiment were NO_3^-, 24%; NH_4^+, 59%; and PO_4^{3-}, 54%. The course of nitrate removal fluctuated greatly and was difficult to evaluate. Average influent concentrations were NO_3^-, 14.1 mg/L; NO_2^-, 0.17 mg/L; NH_4^+, 2.65 mg/L; and PO_4^{3-}, 1.35 mg/L. Water temperature ranged between 12.0°C and 14.2°C.

The course of nutrient removal during the second field experiment was similar to the first, but the maximum levels of NH_4^+ and PO_4^{3-} elimination were much higher (almost 80% and 70%, respectively). Elimination of nitrates was at approximately the same level (22%). The average influent concentrations were similar to those in the first experiment. The temperature of water during this period ranged between 16.1°C and 18.2°C.

Elimination of nutrients stabilized in spite of the increase in periphyton biomass. For practical applications, these results indicate it is best to replace highly colonized screens promptly, allowing biofilm formation for only a limited period.

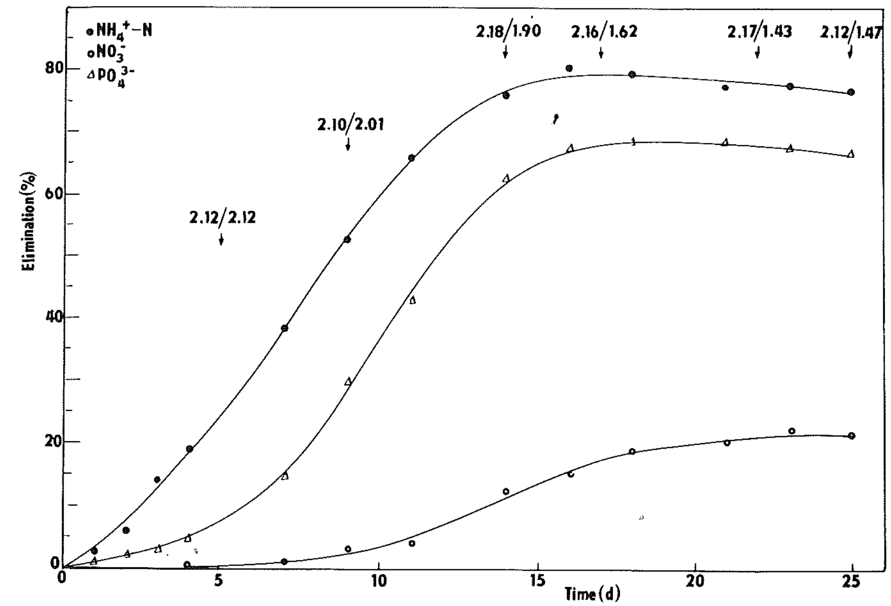

Figure 2. Elimination of nutrients during second field experiment. Numbers indicate values of the saprobic index of periphyton communities—inflow/outflow.

In both experiments, NH_4^+ and PO_4^{3-} elimination appeared almost immediately (after a very short lag phase for ammonium and a bit longer for orthophosphate). The lag phase for nitrate elimination was much longer, and the increase in elimination appeared after filamentous greens were observed in the end of the trough. This timing reinforces the suggestion that elimination of nitrate is connected with activity of filamentous algae species.

Trophic state of the water was determined during the first experiment on the 15th day, after a steady state of nutrient elimination was reached. The value of AGP decreased by 44% in the outflow versus the inflow water (Figure 3). In the second experiment, AGP was also determined when nutrient elimination was at a maximum (20th day). Decrease in the AGP value in the effluent was about 61% in comparison with the influent. The greater decrease in trophic state in the course of the second field experiment corresponds with the higher level of nutrient elimination.

Composition of the influent community was quite steady and identical to the most common naturally occurring periphyton of the Vltava River. The influent community indicated lower β-mesosaprobity and was dominated by the filamentous diatom *Melosira varians*. Other more abundant species were

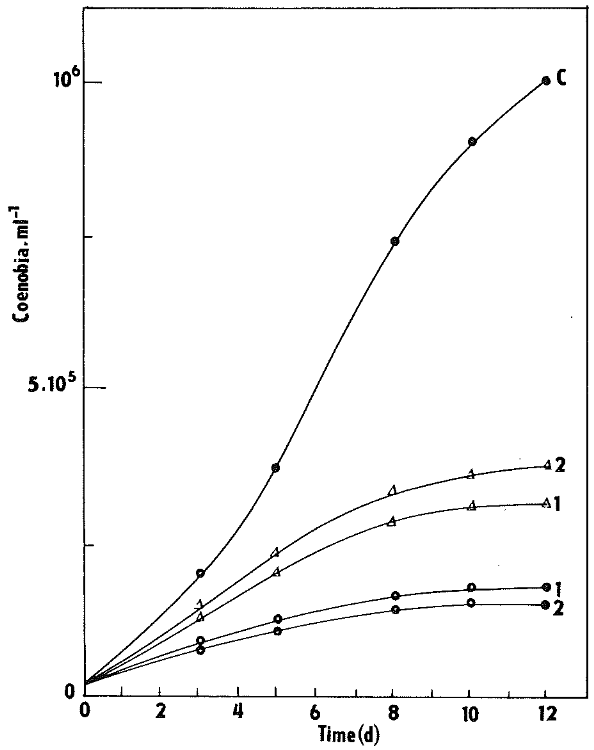

Figure 3. Decrease in trophic state of water in the trough. C = control grown in the artificial medium; 1 = first experiment; 2 = second experiment; Δ = inflow; O = outflow; coenobium = assemblage of four cells.

Oscillatoria sp., *Diatoma vulgare, Gomphonema olivaceum, Navicula cryptocephala* var. *veneta, N. cuspidata, Nitzschia acicularis,* and *Synedra ulna.*

Effluent community structure changed during the course of the experiment (Table 1) in response to a decrease in inorganic nutrients and organic content in the trough. Certain species observed in the inflow community gradually decreased in abundance in the outflow community during the course of the experiment and, in some cases, were not present at the end of the experiment. Such species were *Oscillatoria* sp., *Cymatopleura librilis, Cymbella tumida, Navicula cryptocephala* var. *veneta, N. cuspidata, N. gregaria, Nitzschia acicularis,* and *Nitzschia sigmoidea,* as well as the colorless flagellate *Antophysa vegetans* and stalked, ciliated protozoan *Carchesium polypinum.* All mentioned species prefer high levels of nutrients and organics and belong to the worst β-mesosaprobic or α-mesosaprobic communities.

Some species not present in the inflow community during the course of the experiment gradually appeared and increased in abundance in the outflow community. This was again caused by water quality changes in the trough. Species belonging to this group were: *Achnanthes minutissima, Caloneis bacil-*

Table 1. Periphyton Community Structure Changes During Field Experiments

	Inflow						Outflow					
I. Experiment												
Day of Operation	6	10	12	17			6	10	12	17		
S	2.20	2.23	2.23	2.21			2.17	2.01	1.82	1.71		
C_S	1.00	0.789	0.583	0.489								
II. Experiment												
Day of Operation	5	9	14	17	22	25	5	9	14	17	22	25
S	2.12	2.10	2.18	2.16	2.17	2.12	2.12	2.01	1.90	1.62	1.43	1.4
C_S	0.970	0.732	0.465	0.326	0.254	0.254						

Note: S = saprobic index; C_S = similarity coefficient.

lum, Cymbella helvetica, Diatoma tenue, Fragilaria construens, Melosira italica, Navicula exigua, N. gracilis, N. minima, N. oblonga, N. paleacea, Nitzschia fonticola, Pinnularia borealis, P. subcapitata var. *subcapitata, Synedra acus,* the filamentous greens *Hormidium flaccidum, H. tribonematoideum, Spirogyra* cf. *porticalis,* and *Ulothrix tenuissima* as well as the stalked, ciliated protozoans *Epistylis digitalis* and *Vorticella margaritata,* testacean *Difflugia limnetica,* and rotifer *Cephalodella gibba.*

The periphyton community growing on artificial substrata has proved to be a useful means of nutrient removal from polluted waters. Periphyton growth could be used either in waterworks pretreatment, especially in small eutrophic tributaries to drinking water reservoirs, or in the tertiary treatment process. Before use, however, it would be necessary to check the response under different environmental conditions such as current velocity, influent concentrations of nutrients, size and composition of artificial substrata, or position of the substrata in the trough. At present, these results are successfully being tested for the treatment of agricultural drainage waters with high content of phosphorus and nitrogen.

Note

Detailed results including literature appeared in *Hydrobiologia* 166:225–237 (1988).

CHAPTER 39

Management of Domestic and Municipal Wastewaters

39a Danish Experience with Sewage Treatment in Constructed Wetlands

Hans Brix and Hans-Henrik Schierup

INTRODUCTION

The concept of treating wastewaters with emergent aquatic macrophytes (the root-zone process) was introduced in Denmark in 1983. Basically, this process depends on a horizontal subsurface flow through the common reed (*Phragmites australis* Cav. Trin. ex Steud.) rhizosphere. During passage of wastewater through the rhizosphere, organic matter content of wastewater should theoretically be decomposed by aerobic and anaerobic microorganisms; microbial nitrification and subsequent denitrification should release nitrogen (N) to the atmosphere; and phosphorus (P) should be removed by chemical coprecipitation with iron, aluminum, and calcium compounds in the soil. The most important functions of macrophytes in the reeds beds are (1) to supply oxygen to the aerobic microorganisms in the rhizosphere and (2) to increase/stabilize the hydraulic permeability of the soil. Direct assimilation of nutrients by vegetation is considered to be of no significance for the purification ability of the systems because the maximum amount of nutrients which can be removed by harvesting the aboveground biomass is less than 5% of the load on a yearly basis. Theoretical purification processes in reed beds with subsurface flow have been described.[1]

The root-zone process was introduced as a low-cost, low-technology decentralized solution capable of producing an effluent quality equivalent to, or even exceeding, conventional tertiary treatment technology. Performance for BOD_5 as well as nitrogen and phosphorus was claimed to be better than 90%. The process was a very attractive solution for local municipalities, and the first full-scale treatment facilities in Denmark were constructed during winter 1983–84.