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Bacteria and biofilm (periphyton) in constructed wetlands treating highly coloured nutrient-enriched storm water

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Introduction

Using constructed wetlands for treating storm water is still a relatively new approach in Western Australia, with early examples being retrofitted groundwater recharge basins. More recent examples have been purpose built; the largest and most studied of these is the Bartram Road Buffer (BRB) lakes (Braid 1995). It has been speculated that constructed wetlands in Perth face greater difficulties in treating storm water than elsewhere in the world due to the high DOC and filterable reactive phosphorus (FRP) levels in the water, and the low P retention index of most soils (WRC 1997). Perth has a Mediterranean climate and, as a result, storm water and drainage flows are largely restricted to between May and November; therefore constructed wetlands (and associated plants) have to cope with prolonged dry periods. Despite these difficulties, Lund et al. (2000) have demonstrated that constructed wetlands can have high removal efficiencies of FRP in this environment.

A simple conceptual model for P removal in Australian constructed wetlands was proposed by DLWC (1998). The model (Fig. 1) suggests that overall contaminant removal efficiency (percentage of incoming nutrient load retained by the wetland) is related to three key processes – sedimentation, short-term uptake (sediments and macrophytes) and long-term uptake (biofilm, filtration and litter/peat accumulation). The model does not indicate the magnitude of the processes or the timeline for each. Lund et al. (2000) indicated that macrophytes and sediment were the major mechanisms responsible for P removal in the first 2 years following construction. This study aimed to examine the long-term viability of the wetlands by examining the development of long-term uptake processes.

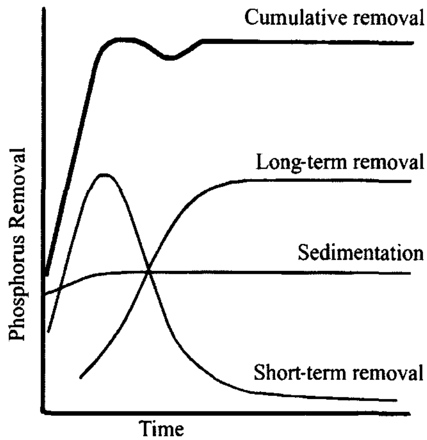

Fig. 1. Conceptual model of the development of key processes responsible for P removal in constructed wetlands (adapted from DLWC 1998).

Methods

Study site

A conceptual design for Henley Brook (HBD) was proposed in 1997, which represented 'best practice' when this project commenced (Jim Davies & Associates 1997). The design consisted of a series of repeating cells, designed specifically to facilitate P removal (Fig. 2). Three experimental ponds (15 m long × 5 m wide) were constructed and supplied by a pump from the Thomsons Lake Main Drain (TLM). This drain supplies the BRB lakes downstream of the site. The ponds were built (June 1998) to represent a single HBD cell at 1:1 scale. The bottom PVC liner was covered by a 0.4-m layer of sand, covered with a 0.1-m layer of Bauxite residue (≈150-µm particle size fraction) neutralised with gypsum. This sediment amendment has been shown to improve P retention on SCP farmlands (see Summers et al. 1996a,b). Each pond was divided along its length into three 5-m wide zones. The inlet and outlet zone was vegetated with the rush *Schoenoplectus validus*, the central open water zone was ~1 m deep.

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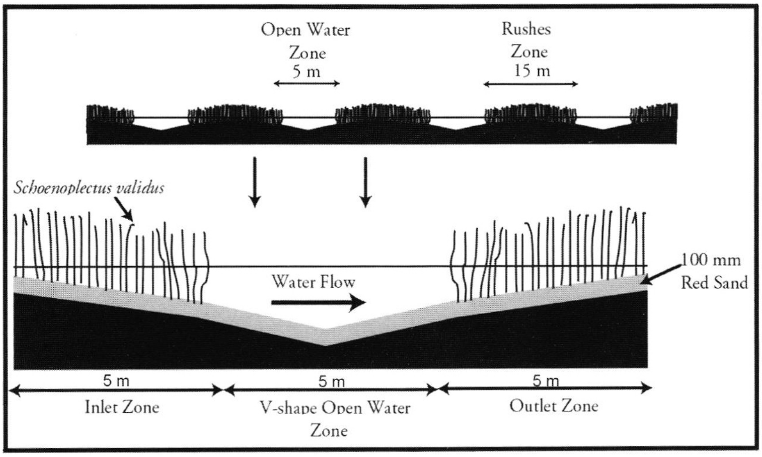

Fig. 2. Illustration of the Henley Brook Design showing the repeating cell design, the lower diagram shows the section used in the experimental pond.

The hydraulic residence time was 8 h and 24 h in 1998 and 1999, respectively, with constant flow rates in each year.

The BRB lakes is an operational-size (5.3 ha) constructed wetland built in 1993, designed to reduce P load into Thomsons Lake coming from the TLM Drain by 30% (Braid 1995). Only the first cell (of five), which had a dense stand of *S. validus* around its margins, and where the sediment had been amended with neutralised fine grade (<150-µm particle size fraction) bauxite residue, was monitored. The cell was divided into two zones (vegetated and open water).

Sampling methods

Sampling was undertaken from 1 October 1998 to 28 November 1998, and from 20 July 1999 to 23 November 1999. Three random sediment cores (44-mm diameter Perspex corer) were collected from each zone in each pond/cell. Cores were divided into 0- to 100-, 100- to 200- and 200- to 300-mm sections, then dried, and loss on ignition (LOI) was measured at 550 °C. Biofilm was measured in each zone at 4 weekly intervals using glass plates (0.0375 m^2) suspended just above the sediment. Four plates were scraped, dried and analysed for total P and total Kjeldahl N, one was scraped for chlorophyll *a* determination, and one plate was used to measure organic and inorganic biomass (through LOI at 550 °C). Total P, total Kjeldahl N and chlorophyll *a* were analysed according to APHA (1998). Leaf decomposition rates were estimated from loss in dry weight of senescent *S. validus* leaves (10 × 0.1-m^2 lengths) placed in plastic onion bags (5- to 10-mm mesh). Eight bags were placed in each zone (August 1998 and 1999) and two per zone were removed in October, January, May and June and reweighed.

Results and discussion

Biofilm biomass was an order of magnitude lower in the ponds and BRB cell (Fig. 3) compared with amounts recorded by Cronk & Mitsch (1994) in constructed wetlands in the Midwestern USA. Cronk & Mitsch (1994) found that biofilm biomass was approximately three times higher in the inlet to the ponds compared to the outlet (30 mg dw m^{-2} vs. 10 mg dw m^{-2}). This was not the case in the present study, probably due to the small changes in nutrient concentrations over the length of the pond (see Lund et al. 2000). The inflow water was highly coloured, with a mean DOC concentration of 50.8 ± 1.6 mg C L^{-1}. This is probably responsible for the low biomass recorded, due to the rapid attenuation of PAR, such that below 0.4 m there is effectively no light available for photosynthesis and/or chelation of essential elements (Lund & Ryder 1998). However, Hawkins (2000) recorded low biofilm biomass in a range of Perth wetlands, indicating that this may be a natural feature of

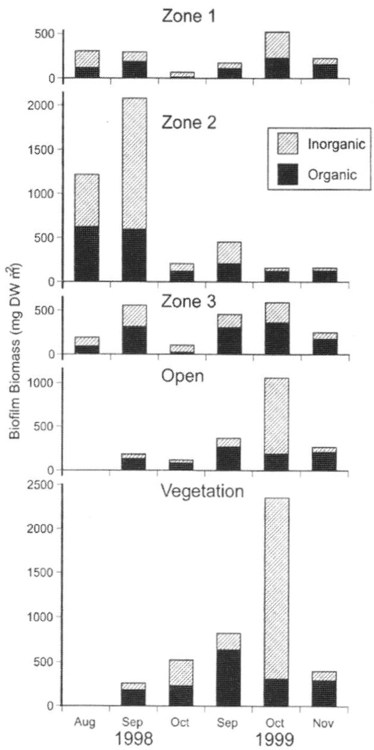

Fig. 3. Mean biofilm biomass (organic and inorganic components) of the three zones in the experimental ponds and the two zones (vegetated and open) of the Bartram Road Buffer Lake cell.

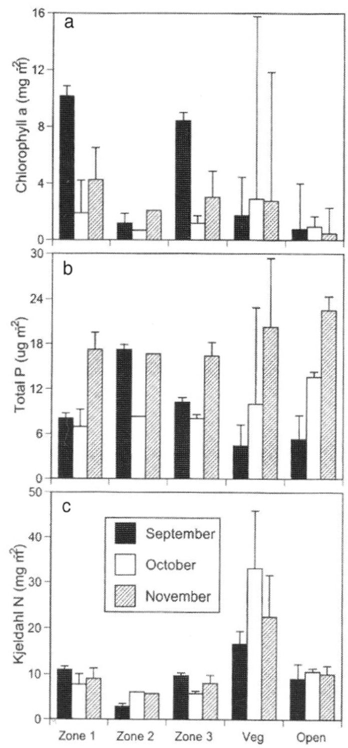

Fig. 4. Mean (+SE) of biofilm (a) chlorophyll *a*, (b) total P, and (c) total Kjeldahl N in 1999 from the three zones in the experimental ponds and the two zones (vegetated and open) of the Bartram Road Buffer Lake cell.

Perth wetlands. Chlorophyll *a* concentrations were typically <4 mg m^{-2} (Fig. 4), although levels in September 1999 in Zones 1 and 3 reached 10.17 ± 3.5 mg m^{-2}. CRONK & MITSCH (1994) recorded similar levels with a range of 2–4 mg m^{-2}. The open-water areas of BRB and Zone 2 had the lowest chlorophyll *a* levels, probably due to the greater water depth and hence light attenuation.

The present study found that organic material accounted for, on average, >55% of the biofilm biomass, compared with <40% found by CRONK & MITSCH (1994). Much of the inorganic biomass within biofilm is composed of trapped fine inorganic particulates. LUND et al. (2000) showed that inorganic suspended solid loads into these systems were relatively low, which may account for this difference.

The pools of P and N within the biofilm of the ponds (assuming a total surface area of 485 m^2 for Zones 1 and 3, and 30 m^2 for Zone 2) varied between 6.2–7.1 mg TP and 3142–5410 mg TKN (Fig. 4). The biofilm is relatively insignificant when compared to other P pools described by LUND et al. (2000). The present study recorded substantially higher (two–three times) biofilm biomass than that recorded by HAWKINS (2000) in the same ponds at the same time. The methodology for collection was similar between the studies although HAWKINS (2000) left the plates in situ for 2 weeks, compared to 4 weeks for the present study. This suggests that biofilm biomass had not begun to plateau for at least 4 weeks. Sloughing off of biomass (turnover) is believed to occur after the plateau is reached (APHA 1998). DLWC (1998) suggested that a key component for the long-term removal of P from constructed wetlands was through biofilm accumulating FRP followed by sedimentation. The low biomass of biofilm and the slow development rate suggest that this mechanism may not be significant in these ponds and in the BRB cell.

LANTZKE et al. (1999) suggested that the major pathways for long-term (months) removal of P loads were macrophyte>sediments>>biofilm. Combined with the results from the present study and those of LUND et al. (2000) this appears to have been the case in these constructed wetlands. Macrophytes are likely to be approaching maximum above-ground biomass after 2 years, reducing their effectiveness as a short-term removal pathway. In the long-term, macrophyte turnover and the eventual accretion of peat within the wetland may continue to be a long-term removal pathway for nutrients. After 7 years of operation, the BRB sediments contained <5% organic matter, compared to 30–80% commonly found in Perth wetlands. No difference was found in sediment organic matter content between BRB and the ponds. The decomposition rates of macrophyte leaves within the wetlands (Fig. 5) was slightly higher in the BRB cell compared to the ponds (regression slopes of 7.3–10.6 vs. 5.0–7.4, respectively) suggesting that bacterial and macroinvertebrate communities may be more established in the older wetland. However, as the highest rate was recorded in the open water zone of BRB this may be a reflection of the faster flow rates through the BRB system. RYDER & HORWITZ (1995) found substantially lower leaf processing rates in a seasonal Perth wetland, suggesting that the flow rate might be responsible for the greater breakdown rates.

Biofilm development appears limited in the constructed wetlands, although whether this is due to the highly coloured waters or is a natural feature of Perth wetlands remains to be discovered. This suggests that biofilm may not be able to make a substantial contribution to long-term

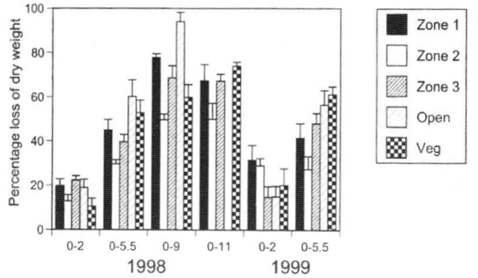

Fig. 5. Mean (+SE) of the cumulative percentage loss of dry weight from the decomposition of *S. validus* over the months starting in August 1998 and August 1999.

P removal. Peat accretion also appears to be relatively slow due to rapid leaf decomposition rates. This suggests that the long-term removal capacity of constructed wetlands receiving coloured waters requires further investigation.

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References

APHA, 1998: *Standard Methods for the Examination of Water and Wastewater,* 20th ed., – American Public Health Association/American Water Works Association/Water Environment Federation, Washington DC.

BRAID, A. J., 1995: *Constructed Wetland Design Criteria: a Study of Their Role in Contaminant Removal from Urban Stormwater Runoff* – Honours thesis, Edith Cowan University, Perth, Western Australia.

CRONK, J. K. & MITSCH, W. J., 1994: Periphyton productivity on artificial and natural surfaces in constructed freshwater wetlands under different hydrologic regimes. – *Aquat. Bot.* **48**: 325–331.

DLWC, 1998: *Constructed Wetlands Manual.* – Department of Land and Water Conservation, New South Wales, Australia.

HAWKINS, S. A., 2000: *Biofilm Composition and Function in Stormwater Constructed Wetland Systems on the Swan Coastal Plain, Western Australia.* – Honours Thesis, Edith Cowan University, Perth, Western Australia.

JIM DAVIES & ASSOCIATES, 1997: *Henley Brook Drive Water Pollution Control Pond Conceptual Design.* – Report No. J294bi.doc, JDA Consultant Hydrologists, Subiaco, Western Australia.

LANTZKE, I. R., MITCHELL, D. S., HERITAGE, A. D. & SHARMA, K. P., 1999: A model of factors controlling orthophosphate removal in planted vertical flow wetlands. – *Ecol. Eng.* **12**: 93–105.

LUND, M. A. & RYDER, D. S., 1998: Can artificially generated gilvin (g440 m^{-1}, Gelbstoff) be used as a tool for lake restoration. – *Verh. Internat. Verein. Limnol.* **26**: 731–735.

LUND, M. A., LAVERY, P. S. & FROEND, R. F., 2000: Removing filterable reactive P from highly coloured stormwater using constructed wetlands. – In: *Proceedings of the 7th International Conference on Wetland Systems for Water Pollution Control.* 1:135–142, Lake Buena Vista, Florida.

RYDER, D. S. & HORWITZ, P., 1995: Seasonal water regimes and leaf litter processing in a wetland on the Swan Coastal Plain, Western Australia. – *Mar. Freshwater Res.* **46**: 1077–1084.

SUMMERS, R. N., GUISE, N. R., SMIRK, D. D. & SUMMERS, K. J., 1996a: Bauxite residue (red mud) improves pasture growth on sandy soils in Western Australia. – *Aust. J. Soil Res.* **34**: 569–581.

SUMMERS, R. N., SMIRK, D. D., & KARAFILIS, D., 1996b: Phosphorus retention and leachates from sandy soil amended with bauxite residue (red mud). – *Aust. J. Soil Res.* **34**: 555–567.

WRC, 1997: *Evaluation of Constructed Wetlands in Perth.* Perth, Water and Rivers Commission. Water Resources Technical Series: WRT20, Water and Rivers Commission, Perth, Western Australia.

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