Case study 7: In-line bioreactor beds Wet Tropics

Project leader and partnerships	Jaragun EcoServices collaborating with James Cook University
Funding source	Department of Environment and Science (Queensland Government Reef Water Quality Program)
Project length	Three years (August 2017 – June 2020)
Region	Wet Tropics, Russell River Catchment (Babinda Swamp Drainage Area)
Production system	Sugarcane
Date of installation	Bioreactor 1: 29-30 Aug 2018, Bioreactor 2: 31 Aug- 1 Sep 2018
Length of installation	Four working days for installation (2 x bioreactors)
Bioreactor type	Twin in-line bioreactor beds (below floor/invert of drain)
Project objective	Research trial to quantify nitrate removal performance.

Summary of the landscape

Low elevation with minimal slope (<1.0%)

Babinda series (peat) and Hewitt series soils (sapric peat overlaying clay). Bioreactor design to fit into existing agricultural drain beds.

Average rainfall and temperature

Annual hydro monitoring period from November 2018 to March 2020. The mean annual rainfall was ~4358 mm (Lat. -17.35°S, Long. 145.95°E), with an average daily temperature of 28.7°C (Babinda, BOM Station No. 31004)

Sizing and volume capacity

20 m long, 0.88 m deep, and 0.99 m wide. Approximately 17.5 m^3 (hardwood woodchip).

Design features

Woodchip bioreactors were installed below existing drain beds with 0.2 m soil cover. Trenches were lined with geofabric, builders plastic then another layer of geofabric. Note: Plastic liner was included to enable accurate measurement of flow through the inlet and outlet of the bioreactor, which was needed to calculate the nitrogen removal rate.

Gabion rock baskets were installed at both ends of the bioreactor to hold the woodchip bed in place. The inlet included 100 mm diameter rock and had an angled rock face to help funnel water into the system. The outlet included 20 mm rock, with a 'halo' of agricultural drainage pipe installed into the rock wall to take water from the entire end drainage face into a 100mm outlet pipe. In high flows, excess water overtops the inlet and flows unimpeded through the drain.

Measuring equipment included two piezometers. A 50mm PVC piezometer was installed into the inlet gabion cage. An outlet piezometer was installed in the woodchip immediately upstream of the gabion rock cage.

Water source

Water in the agricultural drains originates from surface run-off from adjacent sugarcane paddocks and also from shallow groundwater.

Construction methods and materials

A hardwood woodchip mix was used (particle size approximately 50mm, predominantly *Eucalyptus tereticornis* sourced from Gympie, Queensland). The bioreactor beds were dug using an excavator, with a 0.9 m wide bucket (Figure 1).

Figure 1 Construction of the in-line bioreactor bed within an agricultural drain.

The woodchip was encased in plastic heavy duty liner (3mm thick) for the trial to restrict water entry into the bioreactor inlet and water exit via the outlet. The plastic was encased in geofabric to prevent possible puncture. Bentonite clay was used to create a seal around the outlet pipes and piezometers.

The bioreactor bed was capped with soil, dusted with cement and compacted to reduce in-stream erosion. The finished level was to the original drain height.

Costs

$6,653 per bioreactor.

The cost is based on estimates of future construction, using similar machinery, materials and project management needs as the trial. The amount excludes the additional costs of materials, equipment and labour for scientific assessment and monitoring purposes of the trial.

Performance

Average removal efficiency was 41% of nitrogen that entered the bioreactors, with the bioreactors intercepting 7.2% of the total annual nitrogen load in the drain. However, due to low loads, this resulted in a low performance, removing just 0.47 kg nitrogen with a removal rate of 0.07 g N m^{-3} day^{-1}.

Monitoring regime (intensity and frequency)

Water sampling was undertaken fortnightly, over 675 days between May 2018 to March 2020. Samples were analysed for total dissolved nitrogen and oxidised nitrogen. The capacity for denitrifying bioreactors to intercept and remove oxidised nitrogen was assessed by comparing concentrations of nitrogen in inlet and outlet water.

Additional daily composite samples were collected in one of the bioreactors via ISCO 3700. The additional sampling included short periods during the ‘wet up period’, after harvest to capture specific rain events, and periods of known high dissolved inorganic nitrogen loss.

When saturated, salt tracer tests were taken to calculate residence time within the bioreactor beds.

An in-line flow meter (Flomec DP490, Flomec, Sydney, Australia) was initially deployed to measure flow through the bioreactor bed. However, as the resolution was insufficient for the accuracy required, direct measurement of bed outflow was carried out.

Drain discharge was determined using continuous stage measurements and rating curves established using the channel cross-sectional area and occasional velocity measurements. Depth was measured using pressure transducers (CS451, Campbell Scientific, Logan, UT, USA) and recorded with solar-powered data loggers (CR300, Campbell Scientific, Logan, UT, USA). Site specific rating curves were determined by recording water velocity over 2-week deployments of a Doppler instrument (6527 Starflow QSD, Unidata O’Connor WA, Australia) and accurate surveys of the drain cross sectional area using a RTK GPS (Trimble R8 GNSS). Daily discharge was calculated by summing discharge over measured 5-minute intervals.

Troubleshooting

Construction issues included use of heavy machinery along the soft edges of the agricultural drains causing bank collapse. Further collapse was limited by the excavator straddling the drains for construction. Geofabric was applied to reduce additional collapse and left in-situ post construction to reduce future erosion (e.g. from rainfall). Pooling of groundwater in the drain was removed by pump.

Flow through the bioreactor slowed during the wet season, presumably due to clogging by algae, other biofilms and possible fine sediment. This problem self-rectified after completely drying out during the dry season. However, the issue quickly returned after fully rewetting.

What would you do differently?

Re-design of bioreactors to address the above issues, including potential for larger, more cost-effective bioreactors in locations that have continuous water flow.

Jaragun Natural Resource Management

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