Case study 6: Bioreactor beds for aquaculture wastewater, Wet Tropics

Project leader and partnerships	Mainstream Aquaculture collaborating with James Cook University
Funding source	Mainstream Aquaculture and Department of Industry Innovations Connection Grants (2019 & 2020)
Project length	Two and a half years (April 2019 – Aug 2021)
Region	Wet Tropics (Johnstone)
Production system	Land based aquaculture, Barramundi
Date of installation	23 July 2019
Length of installation	One week
Bioreactor type	Six parallel bioreactor beds
Project objective	Research trial to quantify nitrate removal performance and determine suitability on an aquaculture farm.

Summary of the landscape

The bioreactor beds are built on a level area between the aquaculture ponds and treatment wetlands.

Average rainfall and temperature

The area is in the Wet Tropics Region with a mean annual rainfall of 3283 mm. Maximum and minimum average annual temperatures are 28.1 °C and 19.3 °C respectively.

Sizing and volume capacity

Six parallel beds all approximately 10 m long, 1.8 m wide and 1.5 m deep.

Approximately 18 m^3 (softwood woodchip).

Design features

The system was originally designed to include a set of trickle-bed nitrification filters to intercept water coming from the aquaculture ponds and convert ammonia (excreted by fish) to nitrate. This water was then split into one of two header tanks that each feed into three woodchip bioreactor beds.

The header tanks enabled experimentation and testing of the impacts of flow, salinity and nitrogen load. This design gave the ability to run nitrate and carbon dosing experiments in three of the beds and keep the other beds as controls.

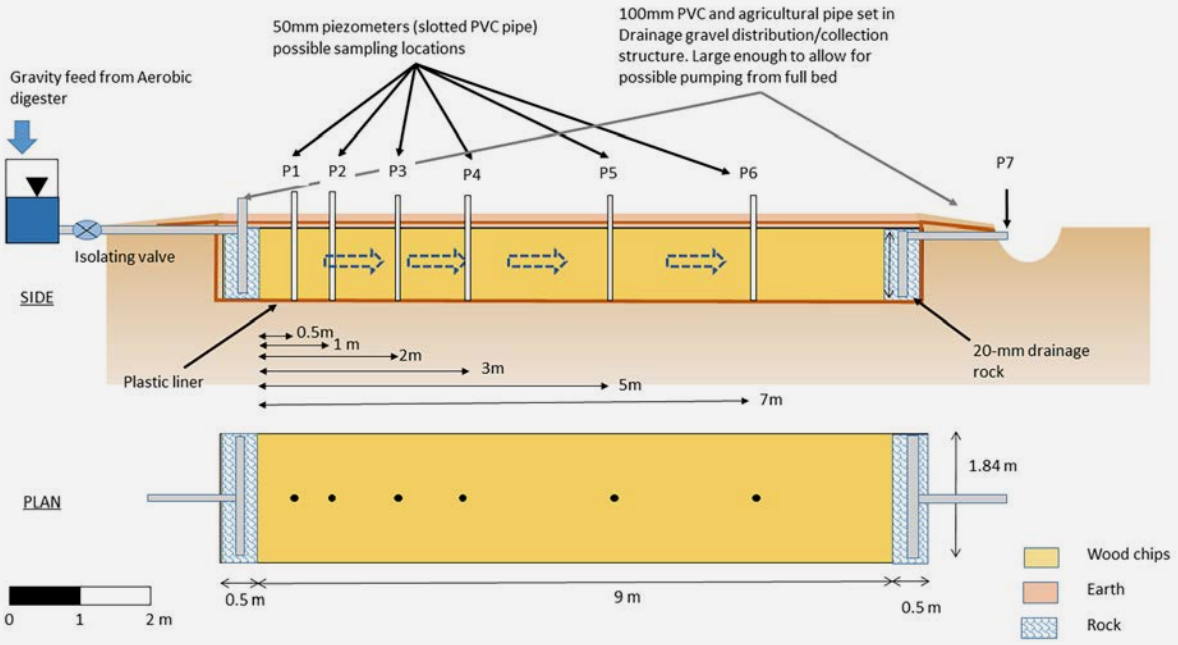

Figure 1 Design of individual woodchip bioreactor bed. Source: JCU

Each bioreactor bed was lined with 3 mm high density polyethylene (HDPE) lining, including a capping piece (Figure 1). This eliminated groundwater and rainwater contamination.

The header tanks ensure that all beds received the same hydraulic head, though each bed has a ball valve on each inlet allowing fine tuning of inflows and thus residence times. Each bed has six piezometers installed to allow for water sampling, with a standard ag pipe 'halo' installed into the gravel filters at both the inlet and outlet.

Water Source

Water is pumped into the system from an adjacent aquaculture pond (stocked with fish). Since January 2021, water has been sourced from an on-site hatchery. This water is treated with a mixed bed biofilm reactor (MBBR) to convert ammonia to nitrate, prior to entering the header tanks and bioreactor beds.

Construction methods and materials

The trenches for the bioreactor beds were excavated using a six-tonne excavator. They were then lined with HDPE liner. Piezometers were installed and the trenches were filled with approximately 20 mm softwood woodchip, sourced locally from timber mills. HDPE liner was then placed over the top of the woodchip (Figure 2).

Other tools and materials required for the build were a dumpy level for height measurements, shovels, rakes, wheelbarrows and a front-loading tractor.

Costs

Not applicable because the systems were over-engineered to provide an ongoing research capacity. The build costs are therefore not relevant to a commercial setting.

Performance

Nitrate removal rate: 9.4 to 13.1 g N m^{-3} day^{-1}

Monitoring regime (intensity and frequency)

The sampling regime involves:

- Monthly or fortnightly collection of samples from i) nitrification filters, ii) header tanks and iii) outlets
- Sampling of all piezometers when a significant change in salinity is observed in the influent water or when dosing experiments are conducted.

Grab samples analysed for dissolved inorganic nitrogen, dissolved organic nitrogen, total nitrogen and ammonium. Alongside grab samples, a probe is used to measure pH, temperature, dissolved oxygen and conductivity.

Troubleshooting

The water was originally sourced from an existing treatment wetland, which was found to have a large amount of organic matter that fouled the nitrification trickle filters. This was rectified by moving the inlet pump to a nearby production pond and bypassing the trickle filters. However, fish excrete ammonia and so nitrate was found to be limiting for bioreactor efficacy.

The system has since been modified to receive water from an onsite hatchery which employs a mixed bed biofilm reactor (MBBR) to convert ammonia to nitrate.

What would you do differently?

To effectively use bioreactor beds to treat aquaculture wastewater requires pre-treatment to convert ammonia to nitrate. Filtration to remove organic matter may also be required.

Figure 2: Woodchip bioreactor beds, showing equipment in the foreground used to add extra nitrate to test performance under different nitrate concentrations. Source: JCU