VERTICAL FLOW WETLANDS FOR INDUSTRIAL WASTEWATER TREATMENT

The largest combination of vertical flow wetlands in Australia is at a chemical and fertiliser manufacturer in Kwinana

SS Domingos, S Dallas, S Felstead

Abstract

Wastewater from CSBP, a chemical and fertiliser manufacturer in Kwinana, Western Australia, comprising stormwater and low-strength process effluent, is diverted to a wastewater containment pond and treated via a series of nutrient stripping wetlands, prior to discharge to the Sepia Depression Ocean Outlet Landline (SDOOL). Firstly, wastewater is successfully nitrified in two fill-and-draw wetland cells operated in parallel. Subsequently, denitrification takes place with the addition of external carbon in a constantly saturated wetland. In an example of industrial synergy, high organic carbon waste streams from neighbouring industries have been dosed into the saturated wetland in order to improve nitrogen removal.

Introduction

The recognition of constructed wetlands for reliably treating industrial effluents is on the rise in Western Australia. Evidence of this is the recent construction of two full-scale vertical flow (VF) wetlands at CSBP Ltd, a chemical and fertiliser manufacturer in Kwinana, 40km south of Perth. CSBP upgraded its wastewater treatment train in 2009 by adding two VF wetland cells of 8,000m^2 each to the already existing 12,000m^2 saturated surface VF wetland, expanding the total wetland area to 2.8ha (Figure 1). The inorganic wastewater generated is characterised by high nitrogen, predominantly NH_3-N, phosphorus and TDS content (and low COD and TSS).

The System

The treatment system includes a containment pond which serves as an equalisation and settling basin. From the containment pond water is alternately pumped into the parallel VF wetlands. Rather than intermittently fed free-draining systems, these cells operate in a sequencing batch (fill and draw) mode. Batches are ideally up to 1,600m^3/day, but can be higher than 2,000m^3/day depending on rainfall and wastewater production. Operation is usually 12hr-filling, 12hr-full, 12hr-draining and 12hr-resting empty. While one cell is filling, the other one is emptying, then resting, and vice versa. The nitrified effluent from the parallel VF cells is pumped into the six-year-old saturated-surface VF system which has woodchips incorporated in the substrate and on the top of the sediment. A full description and performance data for this cell alone can be found in Domingos *et al*. (2009).

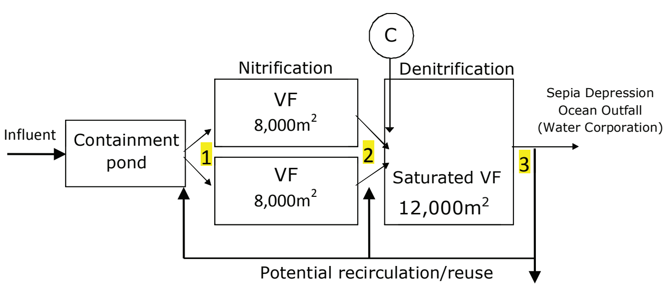

Figure 1: Treatment train at CSBP showing the two new VF wetlands operating in parallel and the six-year-old saturated surface VF wetland. The circle with the letter C going into the saturated VF cell indicates the addition of high carbon content wastewater into the wetland to favour nitrate removal. The numerals 1, 2 and 3 indicate sampling points.

The new VF wetlands have an HDPE liner covered by geotextile and incorporated a 20cm drainage layer of blast furnace slag covering the drainage pipes on the bottom (Figure 2). This layer consists of 15cm of 14mm slag on the bottom and a 5cm intermediate layer of 7mm slag on top (to avoid sand wash down into the slag layer). In an example of industrial synergy, CSBP has used slag from Kwinana neighbour HiSmelt (slag being a by-product of HiSmelt's smelting activities) as the aggregate for the new wetland cells.

The sand used for the 50cm main filtering layer was locally available from the site (Kwinana sits on a sand dune). This fine sand (0–0.5mm), however, would not be suitable for VF wetlands treating wastewaters with a BOD and TSS content, due to clogging potential. The combination of the local carbonaceous sand and the furnace slag was to provide good phosphorus retention capacity and alkalinity to support nitrification in the VF wetlands. The inlet pipe has several spreaders to allow even distribution of water across the surface (Figure 3). Seedlings were sourced from a local nursery and included native *Schoenoplectus* sp., *Juncus* sp. and *Isolepis* sp. (Full aerial photographic coverage of the construction can be scrolled at www.nearmap.com/?ll=-32.237093,115.7631&z=18&t=k&nmd=20110314.)

Figure 2: The drainage layer taking shape – spreading the intermediate 7mm blast furnace slag on top of the 14mm layer. Note the "air" pipes which connect to the drainage system under the slag coming up in the centre and on the batter (far end).

Figure 3: The initial planting stage. Note the inlet distribution pipe covered by limestone rocks and central "air" pipes sticking out.

After four years of continuous operation (2004–2008) the saturated VF wetland presented signs of surface clogging (slow draining of the wetland due to sludge accumulation). This problem was overcome by fully draining the wetland and mechanically removing, by small bobcat, the accumulated sludge and exposing the clear sand underneath over about 50% of the area. Some plant sacrifice was expected with this operation, hence the striped vegetation pattern seen in Figure 4. Within a year vegetation had recovered in the cleared areas. A recommendation to avoid (or postpone) clogging in the saturated VF wetland was to drop the water level to below the surface of the sand to allow drying and oxidation of the accumulated sludge on a monthly basis.

Plant mortality was high in the new cells but survivors grew vigorously in the first year (Figure 5). Even though both VF wetlands are identical in terms of construction and operation, plant development and coverage was much higher in one of the cells for no evident reason.

The effect of the new VF cells in terms of NH_3-N oxidation can be seen in Figure 6. Within three months of commissioning, the pattern of higher NH_3-N and lower NO_3-N in the final effluent was permanently reversed.

From September 2009 effluent NH_3-N dropped to <2.0 mg/L in several occasions, indicating efficient nitrification; as a result TN in the effluent is mainly composed of NO_3-N, therefore the need to reduce it to N_2 in the saturated VF.

Figure 4: An aerial view of the treatment train at CSBP. Alternate fill-and-drain operation is visible on the two VF parallel cells (far end) just prior to planting. Note the transverse vegetation strips on the saturated VF wetland as a result of removal of the top sludge layer to overcome clogging.

As the influent lacks organic carbon (influent COD≈50mg/L), and whatever is available initially gets oxidised in the first-stage VFs, removal of NO_3-N by denitrification can only be achieved with the introduction of external carbon to the saturated VF. Woodchips were added on the surface of the bed as a long-term, slow-release carbon source. The addition of sugar-rich wastewater from a nearby soft drink manufacturing plant has been successfully trialled in the laboratory (data not shown), but the full scale trial demonstrated that larger volumes or more concentrated wastewaters were needed to meet the demand.

In a one-off exercise, acetic acid (1g Ac.acid = 1g COD) was dosed into the wetland at a 5 COD:NO_3-N ratio for approximately three weeks during May/June 2010. This addition resulted in NO_3-N dropping to 2.7mg/L, the lowest concentrations achieved in the whole period studied, July 2009–June 2010 (see Figure 6). The monthly average fell from 70mg/L in May to 12mg/L in June, when acetic acid was dosed. Cost, however, makes this practice prohibitive. More recently, ethylene glycol waste (spent motor vehicle coolant, COD=400,000–600,000mg/L) has been tested and demonstrated to be (as was the soft drink wastewater) a promising carbon source and a good example of industrial synergy with potential environmental and economical benefits.

Figure 5. A VF cell one year after planting.

Influent concentrations of TN (NH_3-N + NO_3-N) are highly variable and can be quite high in isolated events; the capacity of the wetlands in handling these events has been demonstrated. The expansion of the total wetland area has resulted in increased storage and buffering capacity prior to discharge via the SDOOL. This system is, to our knowledge, the largest combination of VF wetlands operated in Australia. Total cost for the construction of the two new VF cells (8,000m^2 each) was AU$2.1million (2009). The wetlands at CSBP will feature as a technical tour destination during the 13th IWA International Conference on Wetland Systems for Water Pollution Control to be held at Murdoch University, Perth, from 25–28 November 2012.

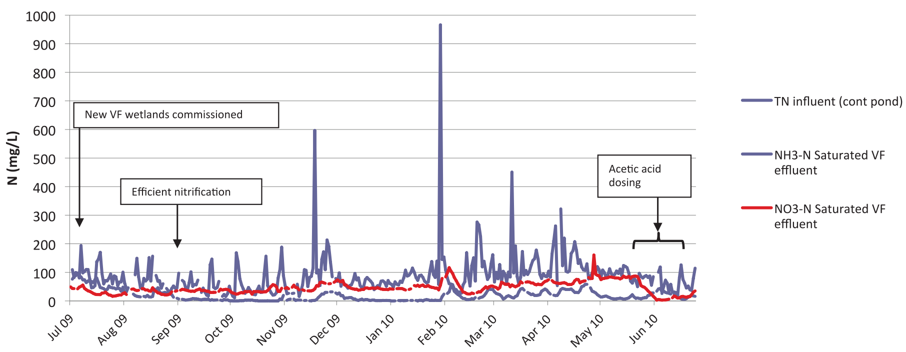

Figure 6: Daily monitoring of N concentrations in the influent (containment pond) and final effluent of the saturated VF wetland systems (sampling points 1 and 3). Influent TN is predominantly NH3-N. Acetic acid addition at COD:NO3-N =5 is indicated by the bracket (May/June 2010).

The Authors

Sergio Domingos (email: s.domingos @murdoch.edu.au) is a PhD candidate and **Stewart Dallas** is Adjunct Lecturer at the School of Environmental Science, Murdoch University, Perth.

Stephanie Felstead is Senior Environmental Advisor at CSBP Ltd, Kwinana, Western Australia.

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