NITROGEN REMOVAL OPTIMISATION FROM COMPLEX WASTEWATER

D.D. Irvine and A. Khan
Pattle Delamore Partners Limited, Auckland, New Zealand

A.F. Findson
Wallace Corporation Limited, Waitoa, New Zealand

ABSTRACT

Wallace Corporation Ltd, utilise a common biological effluent treatment plant to treat high strength wastewater from an industrial complex consisting a meat processing plant, tannery and meat rendering plant. The combined wastewaters entering the treatment plant contain high levels of nitrogen and substantial nitrogen removal is required to ensure compliance with the sites discharge limits.

While the site utilises a combination of discharge to surface water during high river flows and discharge to land during drier periods, maintaining compliance with the consented nitrogen loading rates to land has historically been difficult due to the limited performance of the biological nitrogen removal (BNR) system. In an attempt to overcome the challenges of the annual nitrogen loading rate, Wallace Corporation Ltd sought independent advice to assist with optimising the wastewater treatment plant, especially the BNR system.

An assessment of the waste stream entering the BNR reactors identified that the feed wastewater was carbon short, which was limiting denitrification, in turn preventing alkalinity return and further nitrification. Specific internal carbon sources were identified from one of the processing plants and diverted to the BNR reactor. Given that the BNR reactor was subjected to high strength nitrogenous wastewater, the operational control was modified to ensure pH depletion did not occur.

While the initial plant upgrades resulted in a significant improvement in nitrogen removal, additional opportunities were identified for further nitrogen removal that included changing the process trains and conversion of a reactor to a dedicated anoxic reactor.

The system optimisation was able to utilise existing infrastructure with only minor changes to pipework and control systems. Operational costs were reduced significantly as alkalinity augmentation was eliminated in its entirety and aeration needs were reduced by up to 15%.

The overall improvements to the BNR system have resulted in significantly improved nitrogen removal rates, to over 75% removal, and a reduction in annual nitrogen loading rates to available land by more than 35%. The reduction in annual nitrogen loading rates has created greater opportunities for the dairy farms receiving the treated wastewater, with farm managers now having the capacity to optimise nitrogen application, improving pasture growth and increasing farm yield.

While further improvements to nitrogen removal have been identified, Wallace Corporation can now look forward to greater flexibility with processing rates within the industrial plants and improved farm management

KEYWORDS

Biological nitrogen removal, BNR, industrial wastewater treatment.

1 INTRODUCTION

Wallace Corporation own and operate an industrial complex near Waitoa, Waikato. The site includes a tannery and a rendering plant, along with an adjacent meat plant owned and operated by Silver Fern Farms Limited. The meat plant processes up to 600 head of cattle per day with the rendering plant receiving the meat plant offal along with offal from two other beef plants, casualty stock from around the region and offal from a neighbouring chicken processing facility. The tannery processes cattle hides from a number of sources, initially salting the hides for storage and then wet blue tanning the hides.

Wastewater from the industrial plants is treated in an onsite lagoon based treatment system. The site operates a combined surface water discharge and land disposal system for the management of its treated effluent. During winter when the river flows are high, all wastewater is discharged to the Waitoa River. When the river flow is low, predominantly during summer, the site irrigates all wastewater to land.

The combined wastewaters from all three plants contain high levels of nitrogen which requires a high level of removal in order to meet its surface water and discharge to land consents. While the wastewater treatment plant have been operational for many years, annual nitrogen loading limits for land application have traditionally been fully utilised due to limited performance of the biological nitrogen removal system within the treatment plant.

Over the past 10 years the site had implemented many measures, including a new high rate activated sludge reactor and considerable amounts of alkalinity dosing, with little improvement in the levels of nitrogen being irrigated to land. With the implementation of a dedicated environmental team at the site, Wallace Corporation sought independent advice in order to improve the performance of the biological treatment system to provide a greater level of nitrogen removal.

2 THE WASTEWATER AND TREATMENT SYSTEM

2.1 WASTEWATER CHARACTERISTICS

The raw wastewater flow and characteristics for the three industrial plants waste streams that are treated in the onsite treatment plant are detailed in Table 1. Wastewater from the meat plant is predominantly process wastewater with the majority of the green waste (from the stockyards only) being irrigated to land without treatment. The site implements low temperature rendering (LTR) with the majority of the stickwater (wastewater separated during tallow separation) being treated through waste heat evaporators to recycle solids for product recovery and load reduction on the treatment plant. Both the meat plant and rendering plant wastewaters are characteristically organic.

The tannery effluent, due to the chemical nature of the tanning process, is made up of a combination of organic and inorganic contaminants. The high ammonium deliming liquor waste stream is separated out from the main tannery effluent to avoid additional nitrogen load on the wastewater treatment system and irrigated to land separately.

The wastewater flows from the rendering and meat plants are seasonally based with the meat plant processing peaking during March, April and May which results in a corresponding peak in rendering. Separate of meat plant operation, rendering also experiences increases in processing during the calving season due to casualty stock processing. Tannery wastewater flows remain consistent throughout the year due to the ability to salt and store hides for later processing.

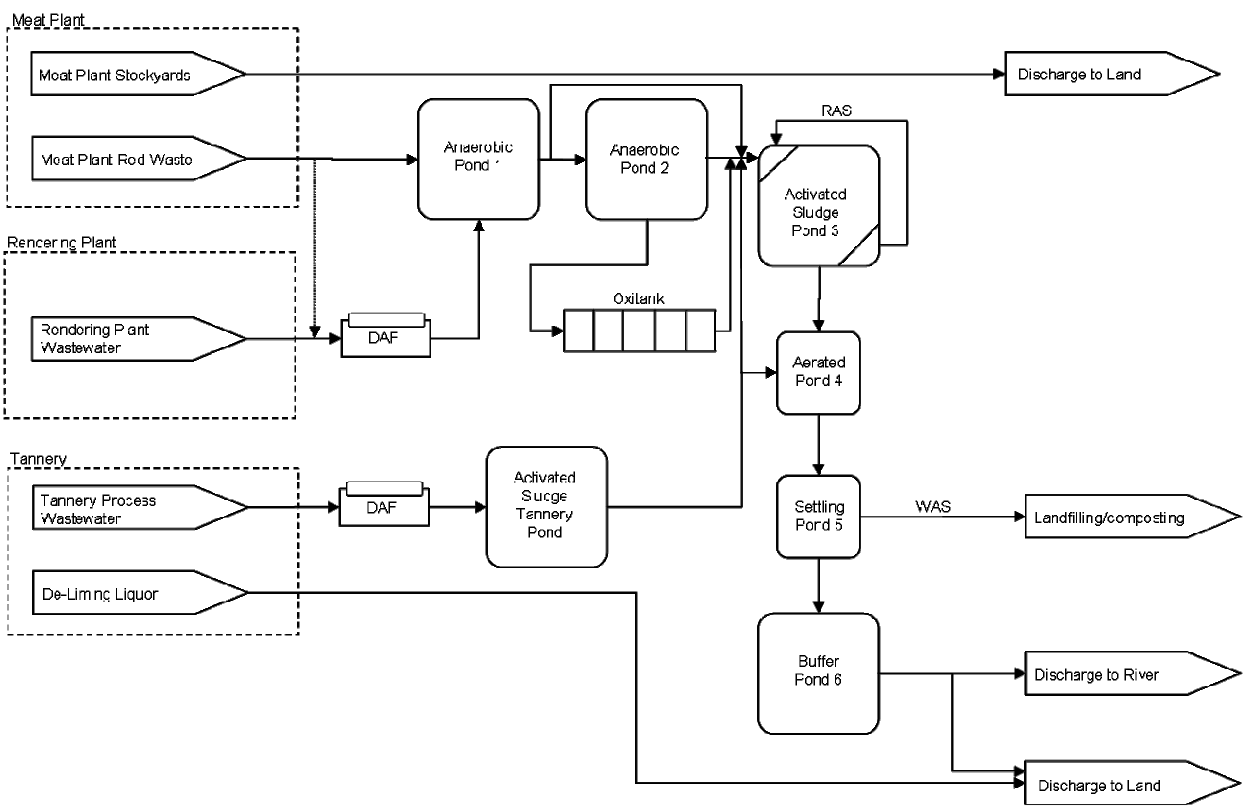
Table 1: Average Wastewater Characteristics

Parameter	Meat Plant Wastewater	Rendering Plant Wastewater	Tannery Wastewater
Flow (m^3/d)	600	400	560
Biochemical Oxygen Demand (mg/L)	780	5900	1940
Total Suspended solids (mg/L)	362	3200	2260
Total Kjeldahl Nitrogen (mg/L)	107	760	370
Total Ammonical Nitrogen (mg/L)	8.0	290	100
Total Phosphorus (mg/L)	4.2	62	7.6

2.2 THE WASTEWATER TREATMENT SYSTEM

The onsite wastewater treatment plant treats wastewater from all three industrial plants. Figure 1 details the wastewater treatment plant process flow diagram prior to amendments to the system.

Figure 1: Wallace Corporation Wastewater Treatment Plant Process Flow Diagram



The rendering wastewater, following physico-chemical treatment in a dissolved air flotation (DAF) reactor, and the meat plant effluent is treated in a series of two anaerobic lagoons. The first anaerobic lagoon is an uncovered reactor, providing for pre-fermentation and limited biochemical oxygen demand (BOD) removal. The second, covered, reactor provides for addition BOD removal.

The anaerobic lagoon effluent is then treated in a series of reactors making up the main biological nitrogen removal component of the wastewater treatment plant. The anaerobic effluent is divided with a portion of the effluent being treated in a high rate activated sludge reactor (Oxitank) and the remainder flowing directly to Pond 3. The Oxitank is a 1,000m^3 concrete tank reactor divided into five sections: anoxic, aerated, aerated anoxic and settle. 30 kW of diffused aeration is provided based on dissolved oxygen (DO) control.

The effluent from the Oxitank was then combined with the rest of the anaerobic Pond 2 effluent and treated in a large activated sludge lagoon (Pond 3). Pond 3 contains 200kW of mechanical aeration, generally operated on DO control. Anoxic zones at the inlet to the reactor and a settling zone (with recycle) at the end of the reactor enables the pond to be operated as a self contained BNR activated sludge system.

Effluent from Pond 3 then enters an additional aerated reactor (Pond 4) prior to a settling lagoon (Pond 5). Settled solids are extracted from the base of Pond 5 and dewatered while the treated wastewater flows to a large buffer lagoon prior to disposal.

Tannery effluent is initially treated separately from the rendering and meat plant wastewaters, with initial DAF treatment followed by a dedicated aeration reactor. The tannery effluent then enters the common wastewater treatment system, with flows being evenly split between Pond 3 and Pond 4.

The combined treated effluent is then either discharged to the Waitoa River during winter (as dictated by the Waitoa River flows) or irrigated to surrounding Wallace Corporation owned dairy farm land.

Stockyards effluent from the meat plant has traditionally been separated from the treatment system to minimise nitrogen loads, with direct irrigation to a separate dairy farm. Deliming liquor from the tannery, which contains very high concentrations of ammonium is irrigated to farmland under a district wide consent.

3 SYSTEM PERFORMANCE AND RECOMMENDED IMPROVEMENTS

3.1 SYSTEM PERFORMANCE

At the time of the initial wastewater treatment system investigation the average total nitrogen concentration in the final treated effluent was approximately 230 mg/L, indicating less than 50% nitrogen removal for the whole system.

With high levels of oxidised nitrogen but also with a high level of ammoniacal nitrogen and a low and regularly fluctuating pH resulting in minimal alkalinity in the Pond 3 effluent, the BNR system was showing classic signs of being carbon short. An assessment of the incoming waste streams indicated that the feed BOD:N ratio was in the order of 2:1, well short of the minimum requirements to ensure efficient biological nitrogen removal. In addition, the manual operation of aeration in Pond 3 was resulting in excessive levels of dissolved oxygen, with minimal potential for denitrification. Due to low levels of alkalinity in the reactor, sodium bicarbonate was added on a daily basis to raise alkalinity and encourage nitrification.

While the Oxitank was designed as a high rate reactor, no nitrification was being achieved in this reactor. The high concentrations of ammoniacal nitrogen in the anaerobic wastewater entering the reactor was suspected to be causing inhibition of nitrifiers, resulting in no nitrification but a net reduction in BOD, exasperating the lack of carbon within Pond 3.

Pond 4 at the time of investigation was being operated as an aerated reactor. While this reactor had traditionally been operated as an anoxic reactor, the use of a mechanical aerator for mixing was resulting in an elevated DO level and minimal potential for denitrification.

The overall BNR system was operated with Pond 5 being utilised as the settling lagoon, with all settled solids being extracted and dewatered. While Pond 3 contained a settling zone with internal recirculation, a wasting pipeline to Pond 4 and ultimately Pond 5 was continually operated resulting in low mixed liquor concentrations in Pond 3. This promoted a high rate of sludge production with little propensity for endogenous decay.

3.2 SYSTEM IMPROVEMENTS

It was concluded from the initial investigation that the system operation could be improved if additional internal carbon supply could be identified and supplied to the BNR system. Dynamic computer modelling suggested that the BNR system (Oxitank and Pond 3) was capable of achieving total inorganic nitrogen levels of between 120 - 130 mg/L, made up of approximately 50 mg/L ammoniacal-N (NH_4-N) and 70 mg/L nitrite-N (NO_2-N) provided that sufficient carbon could be supplied to the system.

A new pipeline was installed to supply an internal carbon source directly to the Pond 3 and Oxitank reactors, from the rendering plant. High levels of oil and grease prevent sourcing of carbon from the main waste streams prior to the anaerobic reactors, however the carbon source identified within the rendering plant contains limited levels of oil and grease but very good carbon to nitrogen ratios. Carbon ratios were also improved by increasing the flow directly from the first anaerobic reactor to Pond 3.

Along with additional carbon, it was recommended that converting the operation of aeration in the Pond 3 reactor to pH control would assist with improving nitrogen removal. Control of aeration rates utilising pH as the control parameter is a very effective method of operating BNR systems with high feed nitrogen concentrations and marginal levels of alkalinity. Provided that sufficient BOD is supplied to the system, control of aeration to maintain the pH between pH 6.5 and 7.0 provides only enough aeration to nitrify, based on the alkalinity that is available, while maintaining very low DO levels (below normal DO control set points) encouraging nitrification and alkalinity return. This method works very well for simultaneous nitrification-denitrification systems. The down side of this method of operation is that it can encourage nitrite formation.

4 TREATMENT SYSTEM RESPONSE

Based on weekly laboratory monitoring results, the performance of the BNR system and the resultant final effluent quality has been graphically presented in Figures 2 and 3. There was a general decrease in effluent inorganic nitrogen concentrations from approximately 230 g/m^3, prior to system amendment commissioning, to approximately 120 g/m^3 in the following six months. The effects of the system changes implemented, through out the commissioning period, are summarised below.

4.1 CARBON DOSING

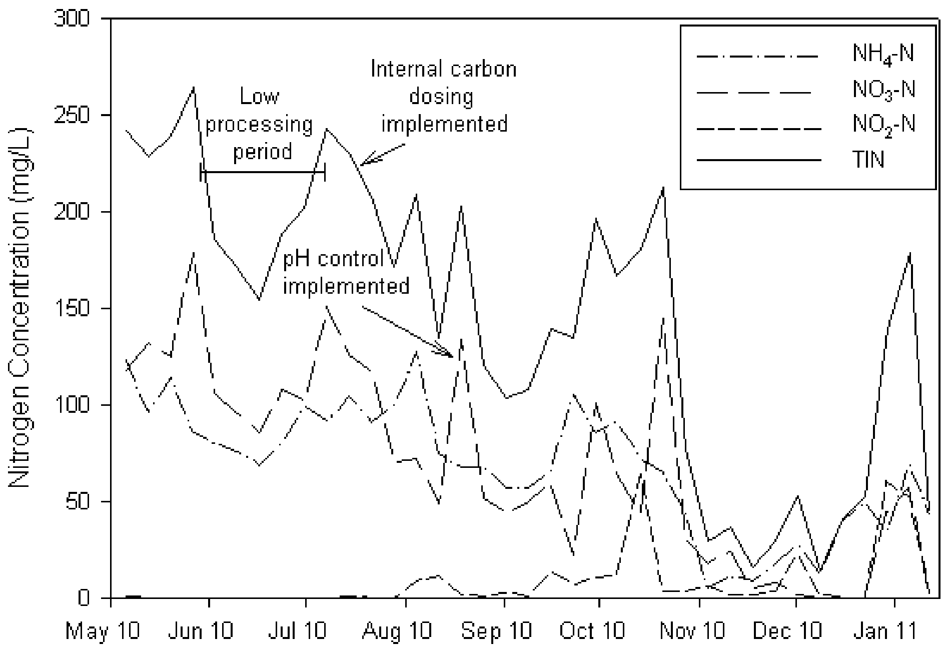
Following commissioning of the supplementary carbon source, the BNR plant was initially sluggish to respond to the amendments due to reduced rendering plant activity. Once the rendering plant processing rates increased total inorganic nitrogen concentration from Pond 3 decreased to about 150 g/m^3.

While the BNR system had improved it was highly dependent on the operation of the rendering plant, providing sufficient supplementary carbon supply flows (as illustrated in Figure 2). Towards the end of the casualty stock season, when rendering began to decrease, the total inorganic nitrogen concentration began to increase again.

At around this time maintenance was being conducted on the Oxitank, temporarily isolating it from service. As a result of this all, supplementary carbon sources from the rendering plant were pumped to Pond 3 only. This had a net benefit on the performance of the overall BNR system with an immediate drop in total inorganic nitrogen concentrations in the Pond 3 effluent from approximately 180 g/m^3 to 50 g/m3. The Oxitank was subsequently removed from service on a permanent basis with the view that it could be better utilised for other process wastewaters.

A high level of nitrogen removal was maintained until the late December 2010 when rendering rates decreased due to the Christmas period, with a resultant spike in both ammonium and nitrate concentrations.

Figure 2: Improvements in Pond 3 Nitrogen Removal Performance



4.2 AERATION CONTROL

For the initial stages of commissioning of the internal carbon source from the rendering plant, DO control was implemented to avoid excessive nitrite levels which would have limited the ability to discharge to the Waitoa River.

DO control offered improved performance over the previous manual operation, however, when rendering rates stopped over the weekend periods, it became an unreliable control parameter, with the pH crashing and nitrification and denitrification decreasing. This resulted in elevate nitrate levels in the river discharge during the early phases of commissioning.

When pH control was implemented, the ammoniacal-N level reduced shortly after, and the nitrate-N level reduced in the following days. Control of aeration rates using pH as the control parameter has remained an effective method of optimising nitrogen removal in Pond 3.

Along with the addition of carbon from the rendering plant, pH control of aeration has resulted in the BNR system sustaining sufficient alkalinity return from denitrification to remove the need for alkalinity addition, while providing over 75% nitrogen removal.

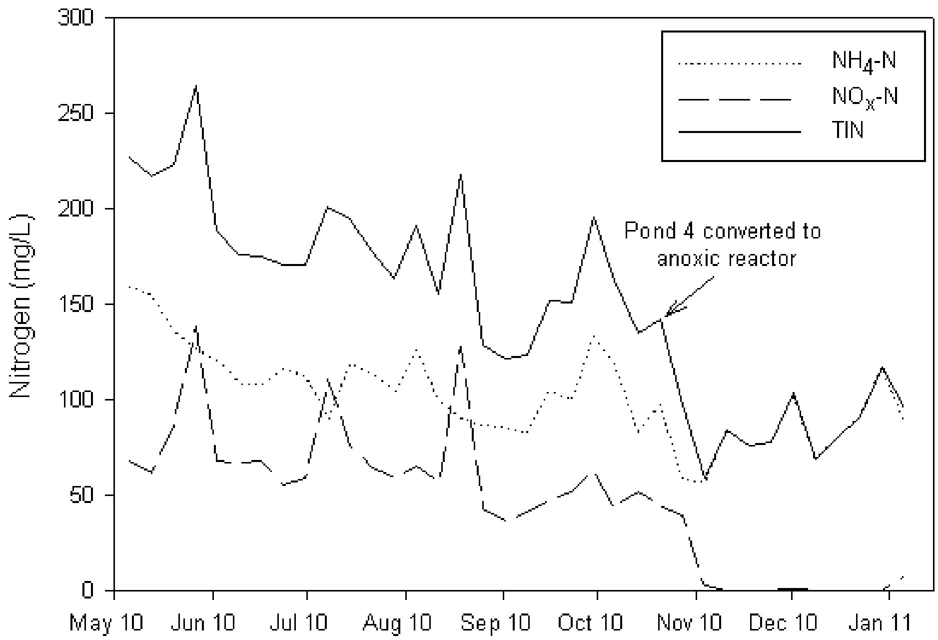
4.3 POND 4 ANOXIC REACTOR

Following commissioning of the supplementary internal carbon source, it was identified that there was residual BOD in the Pond 3 effluent and that this had the potential to assist with denitrification in Pond 4. At the time a mechanical aerator was utilised to mix Pond 4 and there was no solids return to Pond 4 from Pond 5. This resulted in an elevated DO level in Pond 4 and a low mixed liquor concentration.

Modelling suggested that Pond 4 had limited potential to provide additional nitrification and that it would be better suited as an anoxic reactor, providing denitrification of the oxidised nitrogen concentrations in the Pond 3 effluent.

The aerator in Pond 4 was subsequently replaced with a mixer driven off the PTO drive of a tractor, and then subsequently replaced with a fixed mixer unit. The effects of this was an immediate reduction in oxidised nitrogen levels in the Pond 6 effluent (refer to Figure 3). While this change coincided with improved Pond 3 performance (when the Oxitank was taken off-line), the benefits of operating Pond 4 as an anoxic reactor were fully realised over the Christmas period when high nitrate levels were encountered out of Pond 3 but did not result out of Pond 4 (as measured in Pond 6, refer to Figure 3). The general increase in ammoniacal nitrogen concentration between Pond 3 and Pond 6 is as a result of addition of a side stream of tannery effluent into Pond 4, which also assists with denitrification.

Figure 3: Improvements to the Final Effluent Nitrogen Concentrations



Prior to Pond 4 being converted to an anoxic reactor, intermittent increases in nitrite in the Pond 3 effluent had the potential to limit the rate of Pond 6 discharge the River. While this was not a concern for the irrigation activities, it would likely have meant a change to the operating regime during the winter months. With Pond 4 removing almost all oxidised nitrogen from the Pond 3 effluent, the risk of elevated nitrite levels in the Pond 6 effluent has now been minimised.

5 CONCLUSIONS

Prior to the system improvements, the Wallace Corporation wastewater treatment system was achieving less than 50% nitrogen removal throughout the system but were utilising large amounts of supplementary alkalinity addition to maintain nitrification and up to 250 kW of aeration in three separate reactors.

Following the addition of a supplementary internal carbon source, adjustment of the main BNR reactor to pH control and implementation of an anoxic reactor as the final step in the BNR process train, nitrogen removal has improved significantly with the system now providing an average total nitrogen removal rate of over 75% and a halving of the nitrogen load being discharge to the environment. In addition to improvements in nitrogen removal, operational costs have decreased with the removal of alkalinity dosing and a decrease in power consumption from aeration by at least 30kW.

With the main driver for the system amendments being to reduce the nitrogen loading to land from the irrigation system, at the end of the annual monitoring period, nine months following commissioning, the annual nitrogen loading rate to land was 35% below the consented limit. With the system having been previously operated at its maximum consented limit, the reduction in nitrogen loading has allowed the farm managers to more easily manage the irrigation rates to take full advantage of the hydraulic benefits for grass growth, rather than being limited by the nitrogen concentrations. In some cases, supplementary nitrogen fertiliser is being added.

With the current improvements to the system being sustained, Wallace Corporation are now investigating other optimisation opportunities, including utilising the dormant Oxitank reactor of additional final effluent polishing and optimisation of tannery effluent treatment.

While further improvements to nitrogen removal have been identified, Wallace Corporation can now look forward to greater flexibility with processing rates within the industrial plants and improved farm yield.

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