Meat Processing Wastewater Treatment in a Sequencing Batch Reactor

Andrew Slaney and Albert van Oostrom
Meat Industry Research Institute of New Zealand, P.O.Box 617, Hamilton, New Zealand

INTRODUCTION

Meat processing wastewaters contain high concentrations of nitrogen (typically 100 - 250 g m^{-3}). The nitrogen in biologically treated effluent mainly in the form of ammonia and nitrate, both of which can have adverse impacts when discharged into the environment. Reduction of nitrogen discharges is thus an issue facing many meat processing companies.

Traditionally, the New Zealand meat industry has used lagoon-based wastewater treatment technologies, due to their simplicity and low capital operating costs. While adequate for reducing the oxygen demand of the wastewater, these systems, in their current mode of operation, remove very little nitrogen. Typical meat processing wastewater lagoon systems achieve nitrogen removals of 20 - 25% (Russell and Cooper, 1992), whereas many plants are having to reduce the nitrogen levels in their discharges by more than 50% (and some plants by more than 80%) to meet discharge consent conditions. The primary mechanism for nitrogen removal in lagoon systems is biological. MIRINZ studies have focused on modifications to existing lagoon systems, to optimise their capacity for biological nitrogen removal.

Biological nitrogen removal is a two-step process. The first step is the conversion of ammonia to firstly nitrite and then nitrate by autotrophic bacteria (nitrification). The second step is the reduction of nitrate and nitrite to nitrogen gas by heterotrophic bacteria (denitrification). In the absence of oxygen, denitrifying bacteria use nitrate or nitrite instead of oxygen for respiration. Nitrification requires oxygen to be present (aerobic conditions), while denitrification requires the absence of oxygen and the presence of nitrite or nitrate (anoxic conditions). In addition, denitrification requires a source of readily metabolisable organic material to act as an energy source for cell growth, whereas nitrification can be inhibited by high levels of such organic carbon. The key to designing a biological nitrogen removal system is therefore the creation and maintenance of these two different environments.

The sequencing batch reactor (SBR) is an activated sludge process that is particularly suitable for creating separate aerobic and anoxic environments. Unlike biological nutrient removal in continuous-flow activated sludge plants, which spatially separate aerobic and anoxic zones for nitrification and denitrification, an SBR treats the effluent in batches and uses one reactor for all steps. The conditions within the reactor are changed with time to achieve the sequence of nitrification and denitrification described above. SBR's offer a number of advantages over conventional continuous flow systems:

- Increased flexibility. Process changes can be made by adjusting the timing, sequence and duration of the cycle steps, whereas to make similar changes in a continuous-flow process would require resizing of reactors and repositioning of aerators.
- Solid - liquid separation occurs under completely quiescent conditions, giving maximum effluent clarification.
- No biomass recycle system is required, and biomass cannot be washed out by hydraulic surges.
- Automatic control by PLC means minimal operator attention is required.

This paper describes the performance of an experimental SBR system treating meat processing wastewater. The SBR was operated with long hydraulic and solids retention times, to evaluate performance in a situation where a conventional aerated lagoon is converted to the SBR mode of operation, and where sludge production must be kept to a minimum.

METHODS

A 360 litre SBR was used for the investigation. Mixing was provided by an electric motor-driven impeller and baffles. Wastewater was charged to and discharged from the SBR using peristaltic pumps. Rates of filling and discharge were approximately 1 litre $minute^{-1}$. The meat processing wastewater was a mixture of low-carbon effluent from an anaerobic lagoon, and a high-carbon effluent from a short retention time anaerobic flow balancing lagoon. The volume of effluent charged to and discharged from the SBR was controlled by level probes connected to switches. The hydraulic retention time (HRT) was 6 days. A PLC was used to control the operation of the plant.

The SBR cycle duration was 6 hours. The cycle consisted of the following steps: Fill and anoxic react (2.5 hours); aerobic react (2.5 hours); settle (0.5 hours); and decant (0.5 hours).

Aeration was provided by compressed air introduced through two diffusers at the bottom of the SBR. The dissolved oxygen concentration in the SBR was controlled by a DO sensor connected to a data logger that provided on-off control of the air supply. Oxygen uptake rates were determined by measuring the rate at which the DO concentration dropped following shut-off of the air supply to the SBR.

Solids were removed from the SBR at an average rate of 1 litre of settled sludge per day. Due to fluctuations in feed quality, a constant solids retention time (SRT) was not achieved; however, the SRT was estimated to have been between 60 and 100 days throughout the experiment. The SBR was housed in a room maintained at 20 ± 2°C.

RESULTS

Table 1 summarises the characteristics of the influent and effluent over a four week period, while Figure 1 shows the estimated nitrogen balance for the SBR over the same period.

As shown in Table 1, total nitrogen removal averaged 95%. Approximately 71% of the influent TKN was denitrified during the anoxic step, with a further 24% being assimilated into the biosolids fraction (Fig. 1). COD removal was excellent, averaging 95% (Table 1).

Table 1.
Summary of SBR influent and effluent characteristics. Data are mean values for 8 samples taken over a period of 4 weeks.
(all concentrations in g m^{-3})

	Influent	Effluent	% removal
Chemical oxygen demand (COD)	1985	-	95*
Filtered COD	786	93	
Total Kjeldahl nitrogen (TKN)	229	3	99
Ammoniacal nitrogen (NH_3-N)		3	
Nitrate nitrogen (NO_3-N)		9	
Nitrite nitrogen (NO_2-N)		0	
Total nitrogen	229	12	95
Total suspended solids	708	35	95
pH	7.6	6.2	

* calculated as COD in influent vs. filtered COD in effluent.

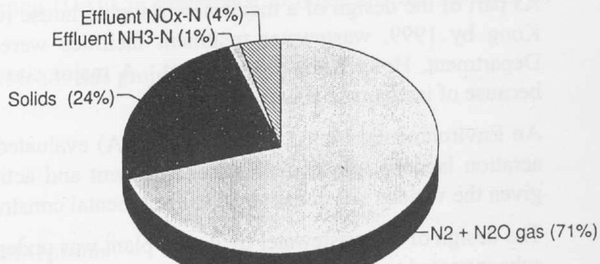

Figure 1.
Nitrogen balance

DISCUSSION AND CONCLUSIONS

The high nitrogen removal efficiency observed was dependent on achieving a sufficiently high influent COD:TKN ratio. This is because readily metabolisable organic carbon is required for cell respiration and growth during denitrification. MIRINZ unpublished studies using anaerobically treated wastewater as a feed source for the SBR resulted in poor nitrogen removal, as anaerobic treatment removes much of the readily metabolisable carbon in the wastewater; thus denitrification of this wastewater was carbon-limited. The importance of adequate COD was also shown in another study using anaerobically treated meat processing wastewater as a feed source for a pilot-scale SBR (Subramanium *et al.*, 1994).

The COD:TKN ratio of the influent used in this study was high enough not to limit denitrification. However, COD is a measure of the total organic content of a wastewater, not just the readily metabolisable fraction. Because the metabolisable COD fraction varies from wastewater to wastewater, the optimum COD:TKN ratio is wastewater-specific. A current MIRINZ research project aims to determine the readily metabolisable COD fraction of various meat processing wastewater streams.

By operating at a long HRT (6 days) and four cycles per day, a small fraction (1/24th) of the SBR volume was discharged per cycle. This enabled most (23/24ths) of the oxidised nitrogen to be denitrified in the subsequent anoxic step (Fig. 1). In addition to enabling high nitrogen removal efficiencies, this is an energy efficient mode of operation, as denitrification reduces the oxygen demand of the wastewater, reducing the aeration requirement.

By measuring the oxygen uptake rate throughout the aerobic step, the total oxygen demand of the wastewater was estimated to be 1560 g m^{-3}. For a plant discharging 1000 m^3 of wastewater per day, this would amount to an oxygen requirement of 1560 kg of oxygen, or approximately 1560 kWh of aeration energy per day (assuming an aerator oxygen delivery of 1 kg O_2 kWh^{-1}).

Solids settling in the SBR was good, with suspended solids in the supernatant averaging 35 g m^{-3} (Table 1). The sludge volume index (SVI) of the mixed liquor ranged from 33 to 100 mL g^{-1}, indicating good settling characteristics.

REFERENCES

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