final report

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Investigations on Ralph's Nitrification/Denitrification Waste Treatment Plant

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Contents

1. INTRODUCTION

1.1 RMIT background

The Chemical Engineering Department students at RMIT all do a final year research project. This project takes place over 12 weeks during the first semester and is expected to take 1 to 2 days of the student's time each week. Most projects are university based but the department likes to get industry involvement and have the students do an investigation of an industrial problem.

The research project needs to be a mix of literature survey, project planning, sampling and analysis, and report write up. The student gives a 20 minute presentation at the end of the project. Clearly, not a great deal can be achieved in such a short project time but it is an opportunity to give students exposure to industry during the period they are considering where they will work when they graduate.

The nitrification/denitrification waste treatment process at Ralph's meat works is an ideal place for such research work. The plant is novel, has been operating for a few years and while doing a good job in waste treatment as measured by waste water discharged, has not been investigated in detail as to what is happening through the process. Dr Ron Brooks initiated the idea of surveying this plant and acted as mentor to the students. MLA, through Sean Starling, supported the idea of doing this investigation and Prof Felicity Roddick encouraged the students to tackle an industry based problem.

In 2002/03, RMIT final year chemical engineering student, Kate McNeill did some measurements of changes in COD throughout the plant and some phosphate analyses but the measurements of ammonia nitrogen did not appear to be correct. After her sampling and analysis work was finished, an MLA report was found of work done at Dinmore which cast doubt on the accuracy of both ammonia and nitrate/nitrite nitrogen analysis by the Merck SQ118 and Merck RQFlex portable instrument methods. She had been using a similar colorimetric method, the HACH test. The report found that only the standard distillation/titration method worked consistently with high accuracy.

An approach was made to James Ralph, MD of "Wagstaff's" to allow a second final year chemical engineering student to study the nitrification/denitrification plant, particularly with regard to doing an ammonia and protein nitrogen survey through the plant using the standard digestion/distillation/titration method. Professor Felicity Roddick was happy to allow another student to work on this project.

1.2 Ralph's background

The abattoir processes about 300 cattle and 2000 small stock (mainly sheep) per day on a single shift system, Mon-Fri. There is no rendering done on site. The inlet water flow volume to the processing plant is measured but no effluent flows.

After pretreatment, Ralph's waste water is treated at one of the few nitrification / denitrification effluent treatment systems installed in the meat industry which uses the CSIRO patented system. Bill Raper (process) and John Green (engineering design), both ex CSIRO scientists were responsible for the system design. One plant operator runs all waste treatment and disposal operations at Ralph's including some sampling and analysis.

The waste water from the plant is first pumped through an elevated rotating screen to remove paunch fibre, and solids from yard washing. This solid material falls into a bin for disposal on land. The screened waste then goes to one of two tanks that have floating skimmers. The underflow goes to the waste treatment plant. The skimmed material containing most of the grease is then hydrocycloned to remove a more concentrated grease and the underflow from the bank of hydrocyclones is fed to a second set of hydrocyclones that remove some heavier than water solids. The grease fraction goes to a tank situated under the rotating screen (saveall) from where it is scraped off weekly and trucked away to rendering, while the heavier solids fraction flows into a small settling tank. The overflow from the settling tank goes back to pretreatment inlet while the solid is disposed of on land.

1.3 The nitrification / denitrification waste treatment process

In anaerobic digestion, organic N compounds are broken down to ammonia N. It was found many years ago that there were bacteria that can grow aerobically and oxidize ammonia NH_3 to nitrate NO_3. But, there are bacteria that can grow anaerobically using the O_2 in NO_3, and if they have an easily oxidisable source of carbon, then NO_3 will convert to nitrogen gas N_2. Thus, nitrogen will be removed from the waste by escaping as nitrogen gas. The CSIRO use this knowledge in the Ralph's nitrification / denitrification plant. Nitrification means oxidizing organic N and ammonia N to nitrate N. Denitrification means turning nitrate N to nitrogen gas.

The CSIRO realised that if they fed some of the abattoir waste directly to the anaerobic digester it would convert organic N to ammonia N. If this was then fed into an SBR containing material already fully oxidized to NO_2 and mixed but not aerated with fresh waste from the plant containing easily oxidisable organic carbon material, then the nitrate would convert to nitrogen gas. This is the successful basis to the Ralph plant. But how well is it working?

1.4 Waste treatment process description

Ralphs process animals on a single shift from 6.00am until approximately 2.30pm and then washdown occurs until about 4.00pm, with a waste flow of about 240,000 litres per day going to the waste treatment plant during this time. The waste water after pre treatment first goes to a splitter box where approximately 70% goes directly to the sequential batch reactor (SBR) and 30% to the covered anaerobic digestor. This ratio varies depending on performance and waste characteristics. The 30% that goes to the anaerobic pond displaces an equal volume overflow from the digestor into the SBR. So while waste water flows directly to the SBR it also flows via the anaerobic digestor. The anaerobic digester has a volume of 2 Ml giving a hydraulic residence (HRT) time of 39 days.

The SBR is an open plastic lined earth tank of 1.25 Ml with a single floating aerator (HRT = 5 to 7 days). The SBR is an activated sludge plant where sludge is aerated with the waste from 2.00pm until 3.00am. The aerator then stops and the sludge settles. A small pump makes a siphon from the SBR into the shallow lagoon that siphons treated waste from the SBR down to a fixed level in the SBR each day. The aerator then restarts. Sludge grows each day in the SBR. Some sludge is pumped from the SBR to the anaerobic digestor daily for about 2 hrs while the agitator is operating. This system has been found to control the volume of sludge in the SBR at a suitable fixed level. The effluent from the lagoon is pumped via a chlorinator into a tank from where it is both tankered to irrigation and used to wash down yards. It meets Class 2 effluent standards.

The biogas generated flows to atmosphere through biofilters. There was no evidence of any odour.

2. RESULTS

2.1 Chemical Oxygen Demand

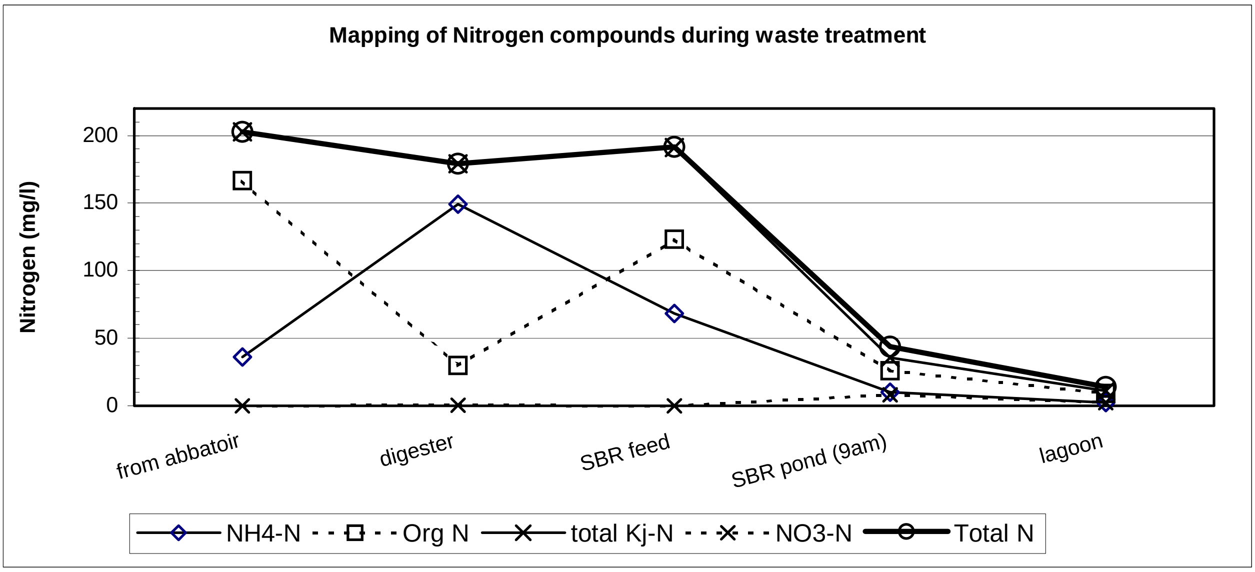
The chemical oxygen demand (COD) was surveyed during the 2002/03 year using the HACH digestor method. The waste flowing to the splitter box was in the range 1,800 to 2,300 mg/l. It was reduced to 450 to 490 mg/l after anaerobic digestion. The average waste flowing into the SBR ranged from 1,400 to 1,700 mg/l. The SBR reduced this flow to 60 to 360 mg/l. This then flowed into the lagoon where the average COD was 77 to 99 mg/l. There was evidence that the COD rose in this final storage lagoon which was probably caused by algae growing in the final lagoon because of the high levels of N and P in the treated waste. The algae fix carbon dioxide from the air and then this converts to COD as the algae die. Storage in excess of 30 days is required in final lagoon storage to ensure pathogen removal.

2.2 Phosphate

Phosphate analyses were carried out in waste flowing from the splitter box, from the anaerobic digestor, and into and out of the SBR at different times. All but one of the ten samples measured was in the range 92 to 100 mg/l phosphate as P. That is, there was no evidence that any reduction occurred through this part of the plant. The average in the lagoon was 81 mg/l phosphate as P. This small fall in phosphate probably occurred due to algal growth.

2.3 Ammonia, Kjeldahl Nitrogen and Nitrite/Nitrate compounds

A survey of Kjeldahl nitrogen ie organic (protein) nitrogen, ammonia nitrogen, and nitrate/nitrite nitrogen were carried out in 2003/04 to find out if any nitrogen reduction was happening through the process ie was there a reduction in total nitrogen due to successful nitrification/ denitrification processes going on. The accepted digestion, distillation, titration analysis method was used. Samples taken were immediately acidified as per standard methods then stored on ice at 0^0 C. The graph below shows the nitrogen map through the plant indicating significant reduction in total nitrogen compounds.



2.4 Overall plant performance

The final lagoon effluent as measured by Water Science Laboratories was

BOD	mg/l	30 to 120	WSL 2004
SS	mg/l	30 to 180	WSL 2004
P	mg/l	16 to 50	WSL 2004
Ammonia N	mg/l	2.3	WSL 2004
Nitrate N	mg/l	2.6	WSL 2004
Total N	mg/l	13.8	WSL 2004

3. CONCLUSIONS

COD removal by anaerobic digestor	77%	RMIT Kate McNeill 2003
COD removal by SBR	95%	RMIT Kate McNeill 2003
COD removal by lagoon	-15%	RMIT Kate McNeill 2003
COD removal overall	96%	
N removal by anaerobic digestion	10%	RMIT Mutia K 2004
N removal by SBR	77%	RMIT Mutia K 2004
N removal by lagoon	68%	RMIT Mutia K 2004
N removal overall	93%	
Phosphate removal by digestor	0%	RMIT Kate McNeill 2003
Phosphate removal by SBR	0%	RMIT Kate McNeill 2003
Phosphate removal by lagoon	12%	RMIT Kate McNeill 2003

1. The nitrification/denitrification WTP achieves considerable nitrogen removal.
2. The plant removes a very large amount of the COD in the waste water.
3. The plant achieves little phosphate removal.
4. The final effluent reaches Class 2 irrigation standard.

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