COMMISSIONING AND OPERATION OF HIGH RATE ANAEROBIC LAGOON (HRAL) REACTORS

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ABSTRACT

The wastewater treatment plants at Mooroopna and Tatura, operated by Goulburn Valley Water, receive food processing and domestic effluent equivalent to half a million people. The existing anaerobic lagoons at these plants needed upgrading to increase capacity, reduce odours and to improve the final effluent quality. High Rate Anaerobic Lagoon (HRAL) reactors were selected for this upgrade in preference to the more traditional upgrade methods of aeration or construction of additional primary lagoons to reduce organic loading rates.

At Mooroopna, the HRAL reactor has enabled the surface area of anaerobic lagoons to reduce from 39 to 2 Ha and in conjunction with the lagoon covers and a biogas flare, has significantly reduced odours. At Tatura, the odour has been almost completely removed following the covering of the existing 3 primary lagoons and flaring of the collected biogas. The efficiency of COD removal in the Tatura HRAL reactor has far exceeded design parameters and is frequently operating in excess of 90% reduction.

This paper discusses the challenges encountered during commissioning and provides some initial operational observations following the conversion of these plants to HRAL reactors.

KEY WORDS

HRAL reactor, covers, anaerobic, UASB, biogas, flare, commissioning, VFA, Alkalinity.

1.0 INTRODUCTION

The Goulburn Valley region is widely recognized as one of the major food production areas of Australia. Large factories in the district process a variety of dairy, fruit and meat products for local consumption and export. These factories produce substantial volumes of wastewater in terms of both hydraulic and organic load. The combined Equivalent Population (EP) of the waste load received at the Mooroopna and Tatura WWTP's is around 550,000 compared to a total residential population in the towns of only 10,000 people.

The existing plants were overloaded and frequently produced unacceptable odours due to increasing production from the factories. The desire of the processing companies to further expand their operations, coupled with a need to reduce odours and produce better quality final effluent to meet tighter discharge requirements, prompted the Authority to investigate upgrade methods. In 1996, Egis Consulting Australia was employed to review various technologies for the upgrade of the Mooroopna and Tatura plants. The HRAL reactor process was seen as an affordable upgrade method, being a low cost, robust technology, easily adapted to the existing plant configuration and with the potential to reduce odours and enhance treatment. A pilot wastewater treatment plant was developed at Mooroopna to assess the anaerobic biodegradability of the wastewater and to determine whether the high sulphate concentrations in the waste would be inhibitory. Smith et al 1998, provides further information on this pilot trial.

Lagoon based wastewater treatment systems have traditionally been used in the Goulburn Valley due to their ease of operation at relatively low cost. Covered anaerobic systems have some advantages over the traditional systems in that:

- They can be used to produce and capture methane which may be utilized for the production of energy and can reduce greenhouse gas omission and odours.
- They produce significantly less sludge than aerobic systems.
- They have the capacity to deal with widely varying organic loads.

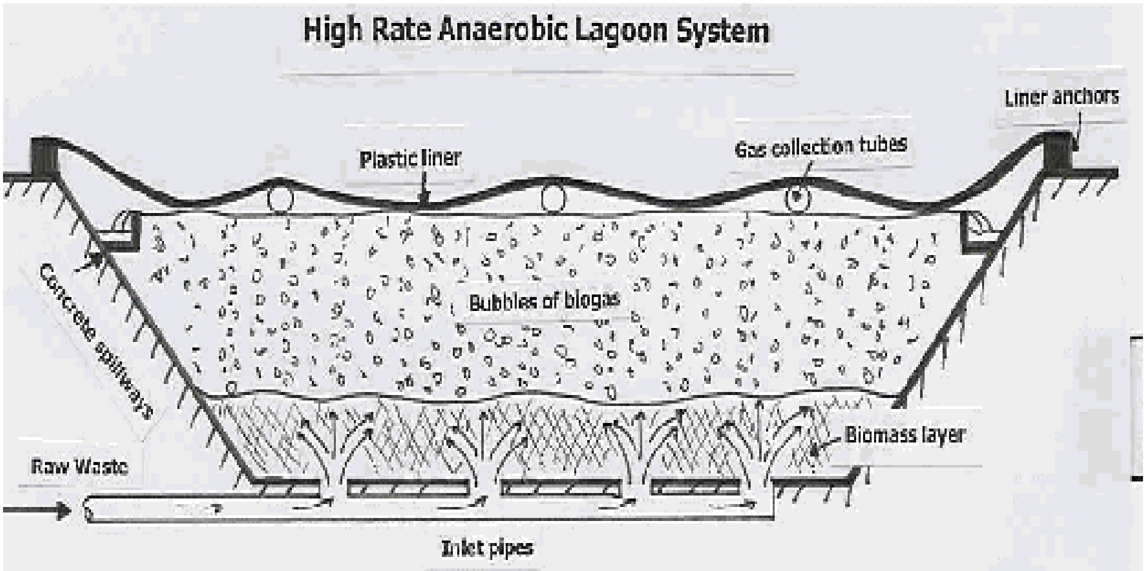
2.0 THE HRAL REACTOR PROCESS AND COMPONENTS

The main function of the HRAL reactor is to convert the bulk of the organic load to biogas whilst expending minimal energy and confining the generation of odorous gases to a small covered area. This enables the biogas to be collected and flared.

2.1 Process

The design concept of the HRAL reactor incorporates similar principles to that employed in the Up-flow Anaerobic Sludge Blanket (UASB) system. Raw waste is fed into the lagoon through a number of inlets spread over the lagoon base. The wastewater passes up through a sludge blanket where the anaerobic bacteria are brought into close contact with the wastewater.

Figure 1 - ***Schematic layout of a HRAL***



Anaerobic degradation is complex, but in simple terms involves a two step process. Bacteria convert the organic material contained in the waste to fatty acids. Carbon dioxide and hydrogen are liberated in this process. In the second and most important phase of the process, methane-forming bacteria convert the fatty acids into methane and carbon dioxide. This methane is then collected and flared to the atmosphere or may be used for the production of either heat or power.

2.2 Loading Rate

A key difference between the HRAL and the UASB system is the organic loading rate. A typical HRAL is designed to operate at a loading rate of between 0.1 and 0.4 kg/BOD/m^3/day compared to a UASB reactor where loading is up to 10 kg/BOD/m^3/day (Smith et al 1998).

2.3 Inlet Distribution and Recycle

Multiple, evenly spread inlets direct flows to the reactor floor to optimize the distribution of the organic load. Recycle of effluent occurs to assist pH buffering of the influent, assist mixing and promote contact of the wastewater inflow with the biomass in the reactor. The upflow process and the generation of gases assist to suspend the sludge blanket and mix the biomass in the lower zones of the reactor. No mechanical mixing is employed.

2.4 Floating Covers

The cover material selected for use at both the Tatura and Mooroopna plants is Reinforced Poly Propylene (RPP). A concrete anchor beam was constructed around the perimeter of the lagoons and the covers attached to this beam using stainless steel fixtures. This system allows the covers to be removed or partially pulled back for maintenance or sludge removal. A ballast tube, filled with cement grout, has been placed on top of the covers to assist with collection and drainage of storm water and to encourage gas migration under the cover.

2.5 Gas Extraction and Flaring System

The gas collection system incorporates floats under the cover to create voids for the gas to flow to and along; a manifold along the edge of the lagoon with control valves to allow the cover to be split into extraction zones; a condensate trap; and large blowers used to create a vacuum and thereby draw the gas to the flare. The flare is designed to incinerate the gas at high temperatures to ensure complete destruction of the sulphide compounds. The covers also have a number of adjustable vent ports which allow gas to vent to the atmosphere if the cover over inflates due to problems with the extraction system. These same vent ports can be used to “sparge” scum build up from beneath the cover.

2.6 Alkalinity Feed

The control of pH through the provision of sufficient alkalinity for anaerobic systems is a vital component of their successful operation. Bulk silos and dosing facilities were established for both the Tatura and Mooroopna WWTP’s to allow dosing of calcium hydroxide (limil) as a supplementary alkalinity source.

3.0 COMMISSIONING

3.1 Establishing Monitoring Protocols

The change to the anaerobic process has brought with it additional opportunities for the plant operators. In order to successfully monitor both the commissioning and then ongoing operation of the reactors, an extensive laboratory was established at the Shepparton wastewater plant. Additional laboratory equipment was purchased and procedures developed to allow the operators to monitor the key processes occurring at each plant. Testing of samples to determine COD, VFA, Alkalinity, TSS, VSS and nutrient concentrations are now routinely performed. This change has brought additional responsibility and skill development to the operators as well as an increased interest, understanding and ownership of the process.

Control charts based on individual plant observations, experiences of others, and literature reviews were developed for the key process monitoring parameters. These control charts assisted during the commissioning process and are now used as a guide to the routine operation of the HRAL reactors. As there was limited experience in commissioning or operating this type of process, the control ranges needed to be regularly reviewed and slightly modified to reflect the increasing knowledge of the process.

3.2 Seed Sludge

At both plants, sludge samples were collected either from within the existing ponds or from a neighboring primary lagoon and tested for the level of methanogenic activity using the acetate uptake rate test.

At Tatura, there was sufficient suitable sludge already established in the base of each of the lagoons. As the main construction works involved the addition of inlet feed pipes to the base of the pond, the existing sludge was pushed behind a small earthen bund and retained within each lagoon. The earth bund was removed on completion of the pipework and the sludge allowed to spread over the base of the lagoon.

At Mooroopna, the HRAL reactor had to be constructed by partitioning, then deepening an existing primary lagoon. In this case, all the sludge was removed to an adjoining pond to allow a dry site for construction. Prior to construction of the new HRAL reactor commencing, modifications were made to the inlets of a neighboring lagoon to direct the raw waste to the base of the pond. This action was to encourage bacteria similar to those needed for the new HRAL to develop. On completion of the HRAL reactor construction, effluent containing the seed bacteria from the adjoining pond was pumped across to fill the HRAL reactor. It was expected that this sludge, plus the extra sludge that would be produced naturally due to the raw waste feed, would be enough to start the process prior to the ensuing canning season.

Onsite testing approximately 6 months after the initial sludge seeding indicated that sludge levels were not developing at a pace that would allow raw waste containing cannery effluent to be turned into the reactor. Additional seed sludge was imported from a neighboring lagoon utilising a floating dredge at that time.

4.0 CRITICAL OPERATING PARAMETERS

4.1 Process Issues

When anaerobic bacteria degrade complex organic material the Volatile Fatty Acids - acetic, propionic and butyric are formed (Johns et al. 1999). These fatty acids are then converted to methane and carbon dioxide by the methane-forming bacteria. There is a delicate balance between production and then conversion of acids in a stable HRAL. If the VFA levels rise too quickly, alkalinity will be depleted and the pH is likely to drop. This may have an adverse effect on the methane-forming bacteria that have a very specific range of pH in which they operate effectively. The 5 point titration method (Moosbrugger 1994) is utilised by operations staff to measure the amount of VFA being produced and the alkalinity within the HRAL. Generally, the results of these two tests provide an opposite mirror effect – when the VFA rises, alkalinity falls.

4.2 Key Elements for Successful Operation

The pH within the reactor is critical for its successful operation due to the sensitive nature of the methane-forming bacteria and should be kept between pH 6.4 and 7.0. Alkalinity should be maintained at a minimum of 800 mg/L to provide buffering capacity and therefore prevent rapid pH changes. This is especially important to accommodate changes in wastewater organic load.

Alkalinity is generated within the process as a byproduct of the conversion of fatty acids to methane by anaerobic bacteria. This alkalinity is accessed in the form of recycled flows to the head of the plant.

The volatile fatty acids level provides an important guide to the reactor biological balance. The COD reduction process requires the nutrients nitrogen and phosphorus, and a ratio of 350 : 5 : 1 has been suggested.

Temperature is very important to the anaerobic process and HRAL reactors are normally operated in the range of 20-38°C. Finally, the rate of load increase must be gradual to prevent upset of the biological balance between fatty acid and methane-forming bacteria.

5.0 TATURA

The Tatura plant receives a base load of milk waste which improves the reactor stability. The removal of COD at the Tatura HRAL has been exceptional. Initial design estimates indicated that a reduction of 60% between the raw waste and the HRAL effluent should be possible. In actual operating conditions during the period October 1999 to June 2000, the median COD reduction was 89% and the absolute reduction has been as high as 95% in March 2000 - *see Figure 2*.

The limil dosing system was commissioned in early October 1999 and in a very short period of time the acid to methane conversion process within the HRAL reactor commenced – *see Figures 2 & 3*. It is likely that the suppressed pH within the reactor was not allowing methanogenesis to occur and raising the pH, through alkalinity addition (limil), was the catalyst required to kick start the process. The limil dosing at Tatura has been able to be turned on and off periodically due to the relative stability of the process, particularly in the warmer months.

Operators discovered a low pH (pH 1.0) entering the plant in February 2000 - *see Figure 3*. This was traced back to a 10,000 litre concentrated nitric acid spill at one of the local factories. Although the operators were able to divert some of this flow away from the HRAL reactors and into other ponds, there was an impact of reducing pH almost immediately and methane production reduced for around three days. Significant shifts in pH also occurred on start up of production at a local tomato processing factory. This increased loading and higher COD, combined with a lower incoming pH, caused a significant reduction in alkalinity and pH which required buffering with limil.

Figure 2 - ***Tatura HRAL - Raw Influent V's Reactor 1 Discharge - COD***

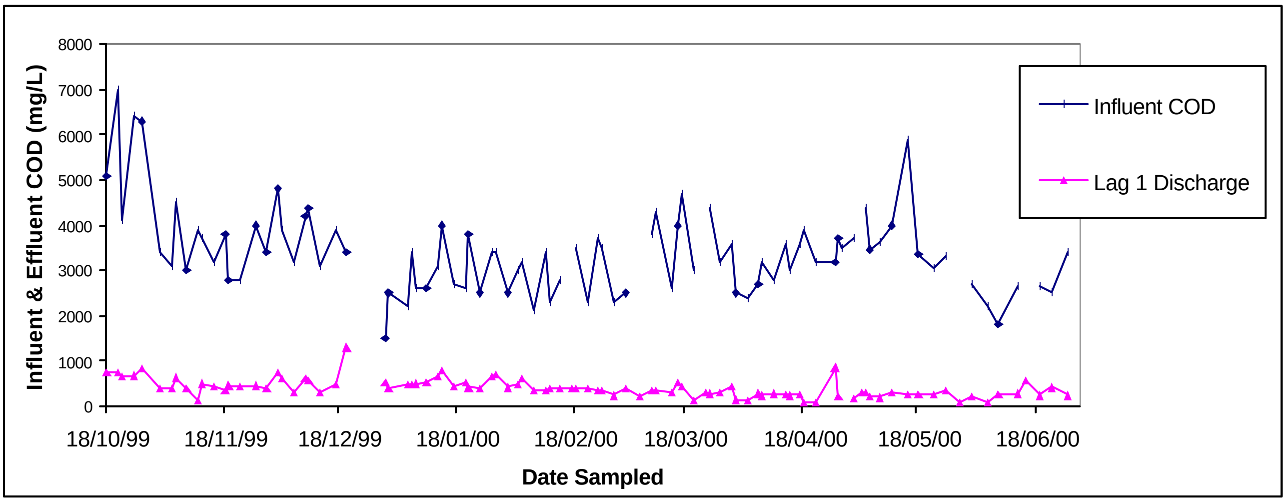


Figure 3 - ***Tatura HRAL – VFA and Alkalinity from Reactor 1 Discharge***

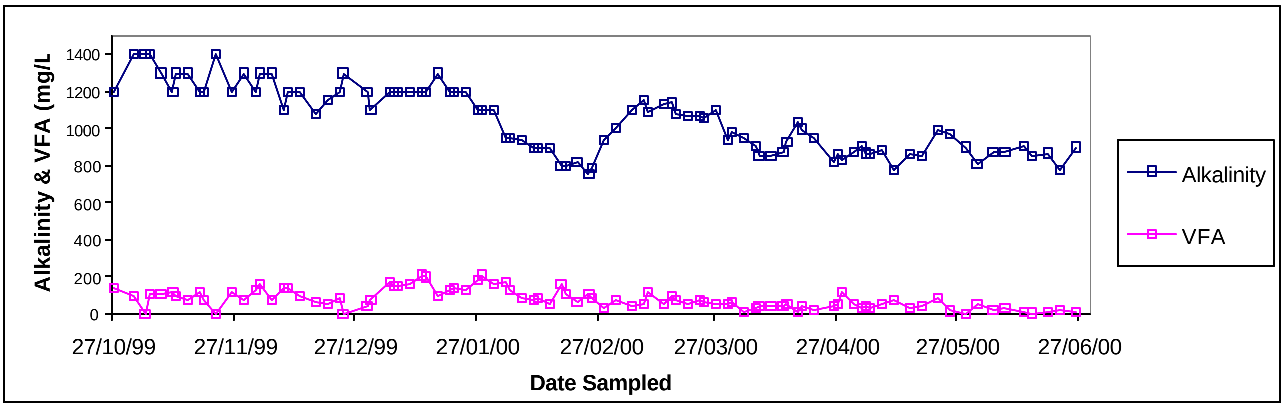
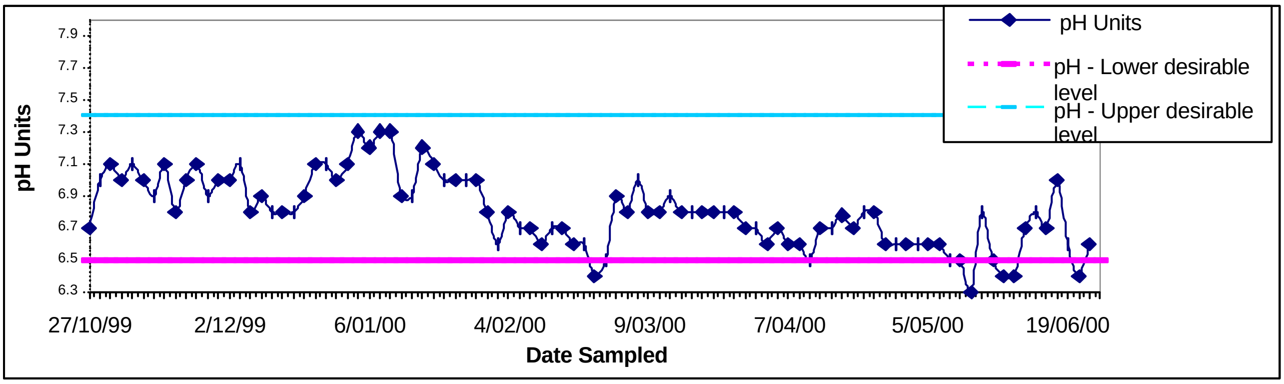


Figure 4 - ***Tatura HRAL - pH from Reactor 1 Discharge***



6.0 MOOROOPNA

At Mooroopna the COD reduction from August 1999 to February 2000 was almost zero - *see Figure 5.* A reduction in COD occurred from mid February, the cause of which is still under review as a combination of reduced load, increased alkalinity dosing and nutrient dosing occurred at that time. In actual operating conditions during the period mid January 2000 to June 2000, the median COD reduction was 51% and the absolute reduction was as high as 65% in March 2000. It is likely that this reduction will increase in subsequent years as the bio-mass builds.

Figure 5 - ***Mooroopna HRAL Raw Influent V's Reactor 1 Discharge - COD***

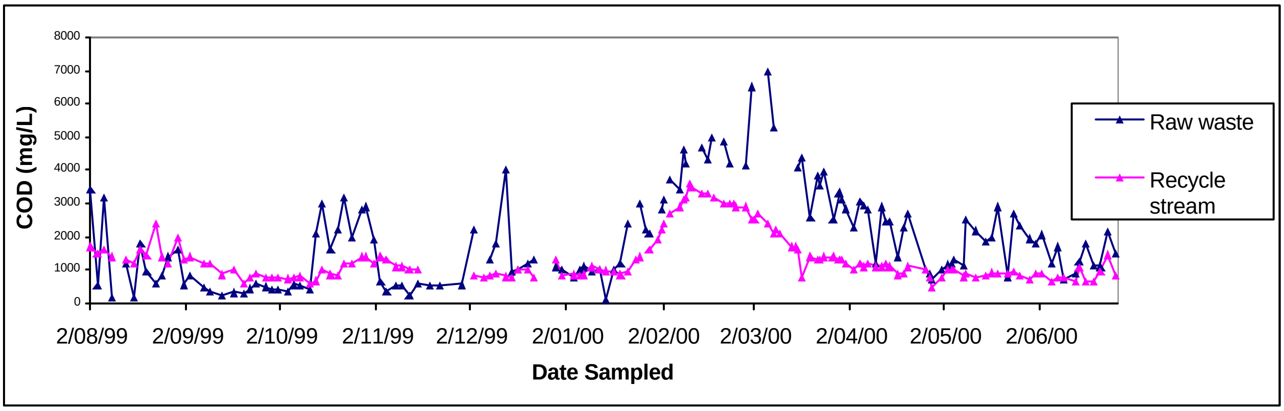


Figure 6 - ***Mooroopna HRAL Recycle pH***

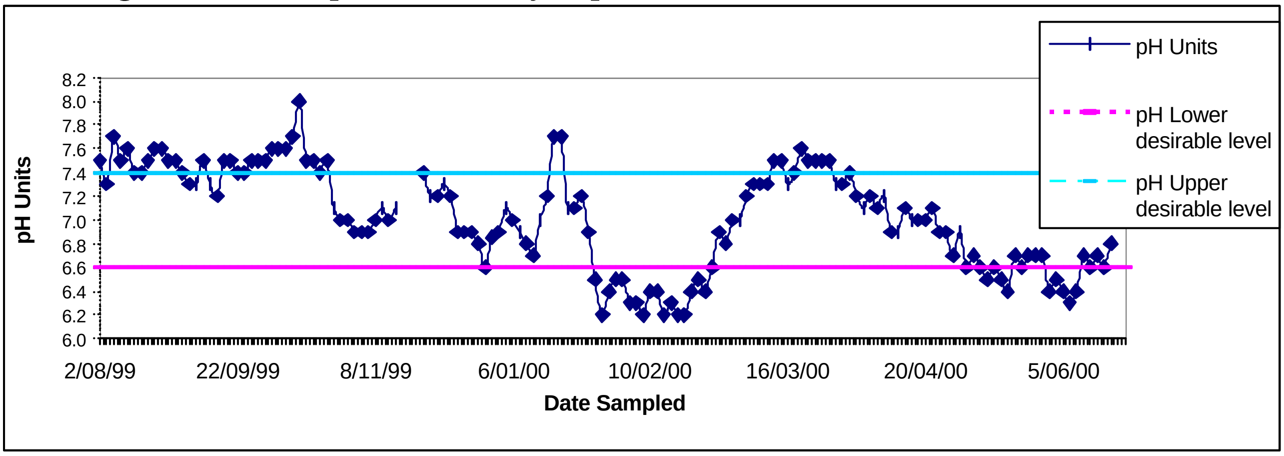
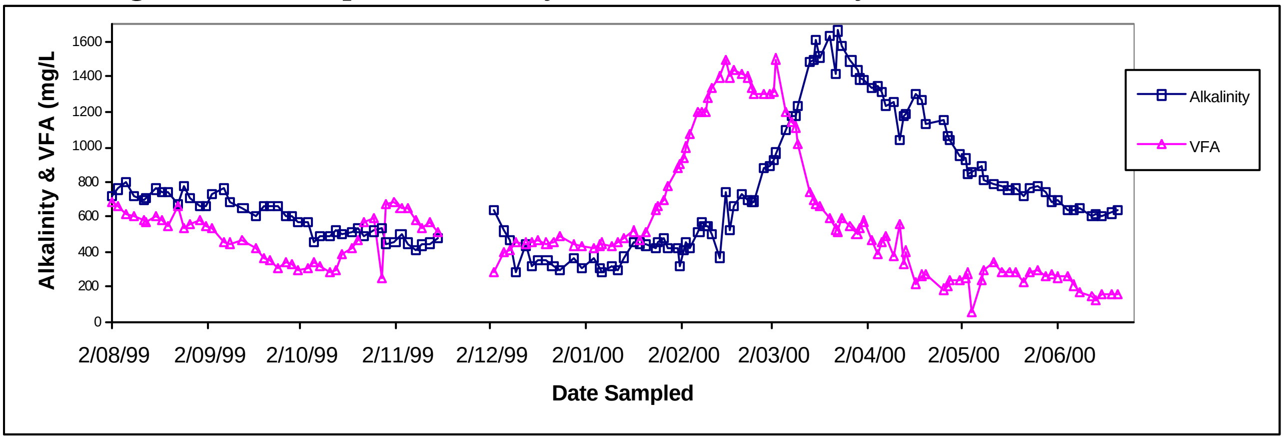


Figure 7 - ***Mooroopna HRAL Recycle VFA and Alkalinity Levels***



By mid January, the HRAL reactor was not able to cope with the rapidly increasing loads from the cannery. There was insufficient active bio-mass present and a substantial reduction in both alkalinity and pH was evident. This necessitated the diversion of the majority of raw waste to the old primary lagoons in an effort to stabilise pH and alkalinity within the reactor.

The limil dosing system is connected directly to the cannery rising main and the dosing plant can only run when the cannery pumps are transferring effluent to the WWTP. The seasonal nature of the cannery processing, with the peak production in summer, meant that it was not possible to adjust the pH and alkalinity in the HRAL in the winter and spring period utilising the limil feeder. It was necessary to set up alternative dosing equipment to enable additional alkalinity, in this case magnesium hydroxide $Mg(OH)_2$, to be added. Around $130,000 was spent on the addition of $Mg(OH)_2$ and $100,000 on limil to stabilise the process to the point that additional raw waste could be gradually fed into the HRAL from around April 2000. It is likely that additional alkalinity will be required at the start of the next cannery season and that some raw flow will need to be diverted early in the season to avoid overloading the HRAL.

The high levels of lime needed to provide the extra alkalinity raised pH levels to above 10, resulting in potential phosphorus precipitation. Nutrient dosing was used to ensure nutrients were available for the anaerobic bacteria. Further investigations are continuing to determine whether nutrient dosing will be required in the future.

7.0 CONCLUSIONS

The use of HRAL reactor technology at Tatura has been a huge success. It is likely that the consistent feed of wastewater emanating from the milk factory has enabled the treatment process to find an efficient equilibrium at an early stage. The odour problem has been almost completely overcome and the treatment efficiency of the reactor in terms of COD removal is in the order of 90%.

Commissioning of the Mooroopna HRAL reactor is not yet complete. It is likely that the level of bio-mass has not yet reached a fully developed state to allow the feeding of the entire peak cannery load. Conservative estimates by various people who have reviewed the data indicate that it may take at least another 12 months to develop the bio-mass to the necessary level. To avoid overloading problems, options for the start of the next canning season including diversion of some raw flow to the old pond system, supplementary alkalinity addition, followed by gradually increasing the applied load, will be considered. These adjustments along with intensive monitoring should ensure the satisfactory completion of the commissioning process.

Careful attention to ensure that sufficient alkalinity is provided to the process and that the pH, measured at the lagoon outlet is maintained at a value above 6.3 is important.

High rate anaerobic lagoons are likely to find increasing application in rural Australia as a cost effective and environmentally acceptable method of treating both domestic and industrial wastewater.

8.0 ACKNOWLEDGEMENTS

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