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Demonstration of Covered Anaerobic Pond Technology

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Abstract

Capturing biogas from covered anaerobic lagoons (CALs) provides a valuable fuel source and greatly reduces carbon emissions. This project aimed to increase knowledge on the start-up and normal operating performance of covered anaerobic lagoons (CAL) so as encourage their uptake by the red meat industry.

CAL performance was assessed by intensive monitoring of the 2.7 ML CAL at JBS Australia's King Island facility for 7 months from commissioning. The CAL started up successfully and showed steady state operation within 6 months. The results show biogas production and quality was affected significantly by many factors. One of the measures used to successfully gauge the health of the CAL was the ratio of volatile fatty acids to total alkalinity. There is a wealth of valuable insight in this report.

Executive summary

Anaerobic wastewater treatment has a long history in the Australian red meat industry. Covering anaerobic ponds with a synthetic cover to capture valuable methane containing biogas offers a means by which the industry can retain the cost-effectiveness of anaerobic ponds while eliminating the greenhouse emissions associated with methane emissions. This project aimed to increase knowledge on the start-up and normal operating performance of covered anaerobic lagoons (CAL) so as encourage their uptake by the red meat industry.

A 2.7 ML CAL was constructed during 2011 at the iconic King Island beef processing facility of JBS Australia with assistance from RIRDC funding. The CAL represented an important component of a new greenfield wastewater treatment plant designed by Johns Environmental. Important components of the CAL included a rotary wedgewire screen for pre-treatment, the 2 mm HDPE liner and cover (Fabtech), a sludge withdrawal system for periodic sludge removal during CAL operation (Johns Environmental) and a biogas train that included a shrouded candlestick flare to incinerate the biogas (ABM).

Monitoring of the CAL performance during the startup and normal operation phases was funded under a PIP grant. The CAL was commissioned on the 12th of December 2011 and was intensively monitored until 7th July 2012. Online instruments collected information on the wastewater feed flow and biogas flowrate, methane concentration and CAL gas pressure. Field and laboratory analysis of the wastewater feed and CAL discharge was performed twice weekly during the investigation period. Other information collected further investigated the crust and sludge build-up, wastewater feed composition and biogas composition.

The CAL achieved design performance and after 6 months of operation consistently produces 85% BOD_5 removal and 5,200m^3 of biogas production per week at an average 70% v/v methane concentration.

Start-up of the CAL required approximately three months to achieve consistent performance. Biogas production reflected the overall anaerobic process efficiency. From start-up, when the anaerobic bacteria flora was being established, there was no significant biogas production for 30 days. The biogas flowrate and methane concentration subsequently increased as the system developed.

During normal operation, there was relatively uniform biogas production over the 7 days of the week despite the 5 day facility operation with some variation in methane content of the biogas during production days. Other biogas components were carbon dioxide, nitrogen, argon, oxygen and hydrogen sulphide (H_2S). Levels of H_2S were low (typically less than 200 ppm), although early morning values were as high as 2,000 ppm (0.2% v/v).

A critical feature of CAL performance is the need to protect the pond from shocks which upset bacterial activity. This is critical where there is reliance on biogas for cogeneration, or as boiler fuel. A major shock was experienced during the project, which adversely impacted biogas production and CAL performance.

Solids accumulation in the CAL was evident within 6 months of CAL operation, although the majority of these are biological in nature and essential for CAL performance. Ten m^3 of sludge was successfully extracted from the CAL through the sludge pipework and exhibited a solids concentration of over 2% by weight. Some crust build-up was evident under the cover despite the low feed oil and grease concentrations. This remains an important issue for CAL longevity.

Contents

1 Background

1.1 Introduction

Anaerobic ponds (without synthetic covers) have long been the cornerstone of meat processing wastewater treatment systems. They provide robust and cost-effective removal of organic loads and their natural tendency to form floating crusts helped minimise odour emissions. However the large quantity of methane-rich biogas emitted from these ponds forms a significant contribution towards direct Scope 1 greenhouse gas (GHG) emissions from meat processing facilities and represents lost fuel value.

Many proprietary high rate anaerobic systems have been installed in industrial wastewater systems and offer the capacity to capture the biogas. Unfortunately these have a poor record with meat processing wastewater largely because of the tendency of high oil & grease and total suspended solids concentrations to interfere with microbial granulation, which is generally critical for successful high rate system function.

The emergence of CALs provides a more appropriate fit for meat processing wastewater. Considerable unknowns and risks exist for CAL technology implementation in the meat processing sector including:

- unknown start-up behaviour of anaerobic systems at green field sites;
- limited data regarding biogas production rates and quality;
- the danger of crust accumulation under the cover causing mechanical damage and eventually cover failure.

The King Island meat processing site owned by JBS Australia Pty Ltd. (JBS) was selected as an ideal demonstration site due to its unique environment. The Rural Industries Research and Development Corporation (RIRDC) contributed capital funding to assist JBS to construct a new CAL with instrumentation and technologies required to demonstrate and monitor its effectiveness. The Australian Meat Processor Corporation (AMPC), Meat & Livestock Australia (MLA) and JBS provided funding to conduct a 9 month research PIP program to monitor the startup and normal operation of the CAL.

This demonstration site and the associated monitoring research project is a first step in ensuring that the red meat processing sector is best placed to develop a suite of strategies and tools able to equip the industry to meet the challenges faced in responding to climate change and to capitalise on opportunities that invariably accompany fundamental change of this magnitude.

1.2 Site Description

King Island, located between Victoria and Tasmania, has a population of approximately 1300 residents. There are about 85,000 head of cattle on the island being 30% dairy and 70% beef. The King Island Abattoir facility was originally built by the Tasmanian Government in the 1950's. In May 2008, JBS acquired the King Island site which currently employs 85 people. JBS have 10 abattoirs throughout Australia, with the King Island site contributing to approximately 1.6% of the weekly beef processing capacity.

The King Island facility is located at Morrison Avenue, Loorara, King Island approximately 7 km north of Currie and adjacent to the airport (Photo 1). The abattoir originally loaded ¼ sides of beef into DC3's at the side fence direct to the airstrip beside the plant, shipping them for processing at their Victorian plants. The location of the airport adjacent to the WWTP has provided some unique challenges.

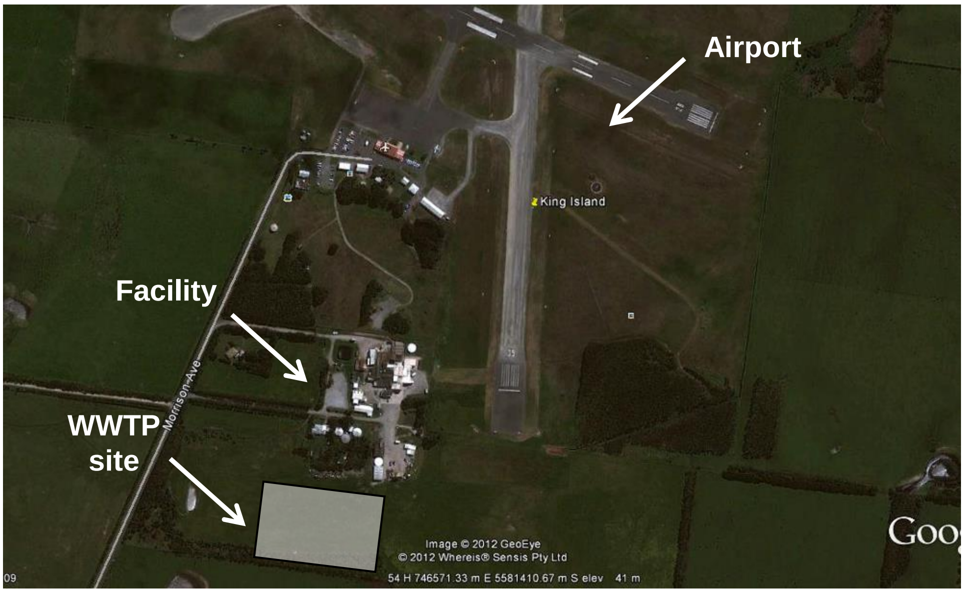


Photo 1: Aerial Photo of King Island site (Google Earth 2012)

1.3 Site Production

The abattoir comprises a beef processing floor which typically operates 5 days/week, 235 days/year processing up to 180 head of cattle per day, on a single kill shift basis with 1 boning shift. There exists a full range of ancillary operations including rendering (HTR), boning and offal and intestine processing. Hides from the processed cattle are dry salted for off-site transport.

Although the abattoir is small relative to most in Australia, it is representative of the larger facilities in being fully integrated and having a full suite of ancillary operations.

1.4 Description of CAL & Biogas System

The CAL was designed by Johns Environmental Pty Ltd [JEPL] as the first of several ponds in a greenfield pond-based wastewater treatment system. The design reflects 20 years experience of the company with anaerobic ponds in the meat processing industry. This section gives an overview of the CAL design for the JBS Australia King Island facility.

1.4.1 Wastewater System

The CAL formed one part of a greenfield WWTP comprising:

- 1 new raw wastewater pump pit, pumps and rising main;
- A new rotary screen to provide fine and gross solids removal. An old DAF was decommissioned and not replaced due to relatively low oil & grease levels in the raw wastewater;
- 1 new 2.7 ML CAL with biogas train and flare;
- Downstream aerated pond with ancillary settle basin and two aerobic polishing ponds.

This project focussed on the new CAL.

1.4.2 Design Wastewater Flows

The major flow is generated on production days. The CAL was designed to handle a production design average flow of 290 kL/day Mon-Fri. This includes some wet weather capture.

1.4.3 Design Wastewater Composition

The wastewater stream design composition post screen and prior to pond treatment is provided in Table 1. These design values are derived from comprehensive testing conducted by JBS during May – July 2010 with samples analysed by EML (Melbourne). The wastewater is typical of many integrated beef processing plants with the exception of low oil & grease concentrations and a high TDS of 5,200 mg/l.

Table 1. Design wastewater composition

Parameter	Units	
Total COD	mg/l	7,250
BOD_5	mg/l	3,000
TSS	mg/l	2,000
O&G	mg/l	120
TN	mg/l	450
Ammonia-N	mg/l	250
TP	mg/l	45
TDS	mg/l	5,200
Calcium	mg/l	115
Magnesium	mg/l	20
Sodium	mg/l	1,500
Chloride	mg/l	1,800
Sulphate	mg/l	65
SAR (calculated)		34
EC	µS/cm	8,500
Temp	^{o}C	30 – 35
pH		7.2

Notes See Abbreviations section for description of parameters.

1.4.4 Design Parameters for the CAL

The design of modern CALs is a compromise between a suitable hydraulic retention time (HRT) and organic loading (OLR) to achieve the desired outcomes which may include:

- Reduction of organic concentrations (BOD_5, COD) to levels commensurate with values desired for subsequent treatment operations,
- Maximal removal of organic load to maximise energy-rich biogas capture,
- Minimisation of sludge deposition in the CAL, and
- Robust CAL operation without pathological conditions, especially microbial foaming which can enter biogas piping and render the system inoperable.

Consequently, there is no one set of HRT and OLR values that can be universally applied for meat processing plants – each site needs a customised outcome.

Key design parameters and dimensions for the CAL at King Island are given in Table 2. The pond has an average HRT of 13 days and a volumetric BOD loading rate of 0.24 kg/m^3/day at the design load. The design BOD removal is 85% to minimise organic load on the downstream ponds. The flare was sized to handle a peak gas flow of 50 m^3/hour of biogas containing 70%v/v/ methane. However, actual design biogas flow is considerably less than this value.

Table 2. Design parameters for the CAL.

Parameter	Units	Design
Design Flow	kL/day	290
BOD load	kg/d	870
Pond depth (TWL)	m	5.0
Wall batter	w:h	2.5
Pond Volume (TWL)	m^3	2,700
Design HRT	day	13
Volumetric loading rate	kgBOD/m^3.d	0.24
Design BOD removal	%	85
BOD_5 exit concentration	mg/l	450
TOW length	m	50.0
TOW width	m	26.0
Base length	m	28.0
Base width	m	4.0
Freeboard	m	0.5
Design biogas production	m^3/day	600 (7 day/week)
Design methane content	%v/v	70
Design flare biogas flow	m^3/h	50

Notes: TWL – top water level; HRT – hydraulic retention time.

1.4.5 CAL Detail

The CAL has one inlet pipe and one outlet (Photo 2) both in 160 mm OD HDPE. The inlet is centred on the longitudinal centre line at the north end and empties at 1 metre below top water level. The outlet is positioned off-centre at the South end of the CAL. A weir in the pre-cast concrete outlet pit sets the liquid depth in the CAL at 5 metres.

Photo 2: King Island CAL

The cover was designed and fabricated by Fabtech (Wingfield, SA) and comprises 2.0 mm HDPE anchored in a trench on the perimeter of the CAL (Photo 3). The CAL is lined with the same material to prevent leakage into the shallow groundwater. The cover is equipped with:

- Central walkway of textured HDPE welded onto the cover;
- 2 sample ports with bolted flange closures – one near the inlet, the other nearer the outlet;
- 4 emergency vent PVC spears designed to release overpressure, and
- An "H" shaped stormwater removal weighting system to capture stormwater (see Photo 3) with a float valve drawoff near the outlet to a centrifugal pump located adjacent to the outlet weir and discharge into it (Photo 4).

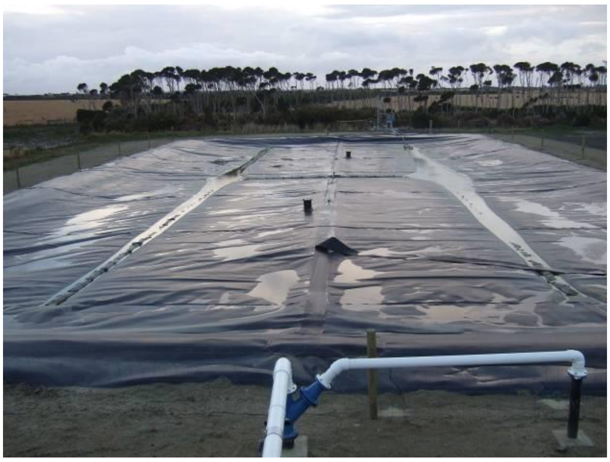


Photo 3: CAL cover

Photo 4: CAL showing stormwater removal

1.4.6 Biogas Train

The biogas train and flare was fabricated by ABM (Carrum Downs, VIC). A shrouded flare was selected since the location is reasonably remote and very wind exposed. The biogas system is pictured in Photo 5 and consisted of:

- Knock out pot for condensate capture with provision to isolate it for maintenance;
- A blower to feed the biogas to the flare;
- Emergency valve shutdown and flame arrestor;
- Shrouded flare with pilot able to be lit from the 9 kg gas bottle;
- Metering of biogas flow (FCI ST51 meter) and methane content (Draeger polytron analyser). These data were logged to the facility SCADA in addition to operational flare information.
- A pressure transducer to measure gas pressure under the CAL cover. This pressure was used to control flare burn rate settings.

Photo 5: Biogas train

The original intent for JBS was to run a small (30 kWe) gas engine, but the decision to install this has been put on hold.

1.4.7 Sludge Removal

Provision was made for sludge removal via a single 160 mm OD HDPE sludge extraction pipe positioned longitundinally down the centre of the pond base. The pipe was capped at the north end and exited horizontally through a penetration in the liner at the south end (Photo 2). This end performed a 90^o bend to the vertical and terminated at ground level in an upstand with camlock and cap fitting to allow connection to a sludge pump or truck. The upstand was embedded in a concrete slab to minimise movement during pumping (Photo 6).

Photo 6: Sludge pipework upstand

Photo 7: Sludge pipework weights

The pipe was elevated approximately 200 mm off the CAL base by a series of 160 mm OD concrete-filled weights to minimise movement of the pipe and to negate its buoyancy if filled with biogas. The weights were capped water tight with HDPE caps to prevent concrete erosion in the slightly acidic conditions in the CAL (see Photo 7) and held in place by straps welded to a HDPE wear strip.

The pipe (24 m length on the pond base) was drilled with 16 x 30 mm diameter holes for sludge entry. The holes were on alternate sides of the pipe and positioned to avoid the weights. The hole spacings increased as the distance to the sludge discharge point reduced to avoid rat-holing as much as possible.

2 Project objectives

The project goal was to demonstrate the operation of covered anaerobic pond technology to drive the uptake in Australian meat processing industry.

The project objectives were to:

- Collect and analyse CAL data from a rigorous monitoring program over a 9 month period. The data sought to capture two critical stages of CAL operation:
    - Start-up phase. This can be reasonably lengthy, especially for greenfield sites. There are no publically available data regarding this period for meat processing ponds;
    - Normal operation. Of special interest is the impact of the usual 5 day on/ 2 day off processing week on pond operation and biogas production and quality.

  This data will help to reduce the uncertainties, risk and cost of installing methane recovery and use systems in the red meat processing industry.
- Investigate sludge accumulation and crust build up over the investigation period.
- Communicate the benefits of methane recovery and use as a clean energy source through final deliverables.

3 Methodology

3.1 CAL Start-up

Figure 1 outlines the timing of the construction and operation phases of the project. There were extensive delays due to wet weather during excavation.

Cover installation is preferably conducted on a filled pond. For greenfield sites this is a challenge since the good quality water preferred for filling (such as treated effluent) is not readily available and potable water is expensive. At King Island the pond was initially filled in November 2011 with a mix of bore water and raw wastewater. No difficulties were experienced using this mix.

Commissioning was initiated by adding the full wastewater flow into the CAL on the 13th December 2011. The entire wastewater flow continued to enter the CAL from this day onwards. No inoculum or sludge was added to assist startup due to the remoteness of the site and the absence of other suitable wastewater treatment systems on the island.

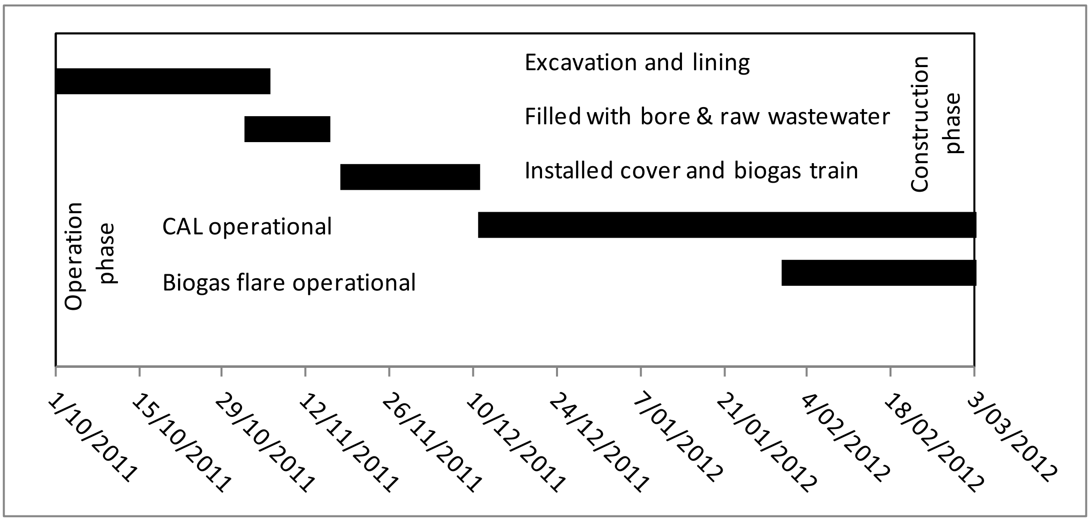


Figure 1: CAL start up time line

3.2 Wastewater Monitoring

Wastewater monitoring enabled the characterisation of the effluent flow and quality entering and leaving the CAL.

3.2.1 Wastewater Flow

Wastewater flow into the CAL was measured on-line using a Siemens magflow meter installed on the rising main from pump station 1 to the new rotating drum screen upstream of the CAL (Photo 8). The flowmeter recorded instantaneous and totalized flow and communicated with the plant’s SCADA system. JBS provided JEPL the daily raw wastewater flows entering the CAL, daily SCADA output and daily production information.

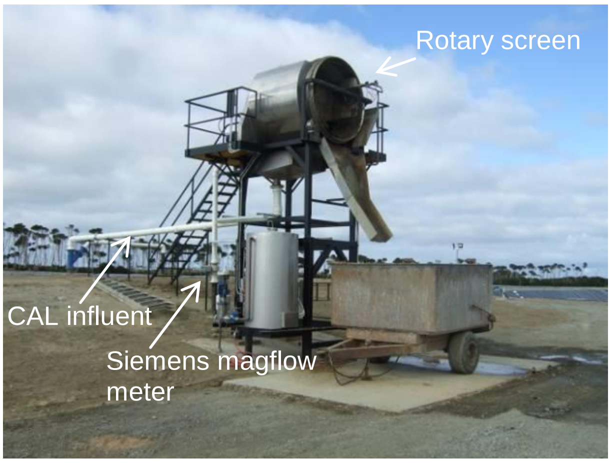


Photo 8: Screening and instrumentation upstream of CAL

3.2.2 Wastewater Characterisation

Readily accessible sampling points at the inlet and outlet of the CAL were an integral feature of the design. The inlet sampling point (Photo 9) is a ball valve directly prior to the CAL inlet. The outlet sampling point (Photo 10) is the weir overflow between the CAL and the next treatment pond. An access point for sampling was fitted into the galvanised steel grate enclosing the outlet pit. Note that the access point was sized to prevent human entry into the pit, due to its hazardous nature.

Photo 9: CAL inlet sampling point

Photo 10: CAL outlet sampling point

Wastewater feed and CAL discharge composition was analysed by field instrumentation and an off-site laboratory twice per week. The detailed sampling description is given in Appendix A.

1. Field measurements by King Island personnel recorded pH, temperature, and conductivity using a portable Hach HQ40d instrument supplied by JEPL. The visual appearance and odour of the effluent was also noted.

2. Laboratory analysis by EML (Chem) provided information on the following parameters; pH, COD, BOD_5, oil and grease, TSS, volatile fatty acids (VFA), total alkalinity (TA), ammonia and total kjeldahl nitrogen measured as TKN.

Raw effluent composition over a typical production day was investigated three times during the monitoring period. Raw effluent samples were collected over a typical production day and analysed by field instrumentation and laboratory analysis. The frequency and handling of each sampling regime are as follows:

1. 9th February 2012.
   8 equal volume grab samples collected at approximately 1 hour intervals over production day and composited for laboratory analysis.
2. 4th June 2012.
   6 equal volume grab samples collected at approximately 1 hour intervals from 11am to 4pm and composited for laboratory analysis.
3. 5th June 2012.
   a. 11 equal volume grab samples collected at 1 hour intervals from 7am to 5pm, analysed for pH, temperature and conductivity using field instrumentation and composited for laboratory analysis.
   b. 6 grab samples collected at 2 hour intervals from 7am to 5pm, analysed for pH, temperature and conductivity using field instrumentation and individual samples sent for laboratory analysis.

3.3 Biogas Monitoring

Online biogas monitoring of the methane composition, biogas flow and the pressure under the CAL cover was recorded to the sites SCADA system. An example of a SCADA output is shown in Appendix B. Further laboratory and field analysis of the biogas was performed by The Odour Unit on 5th and 6th June 2012.

3.3.1 Biogas Flow

Instantaneous and cumulative biogas flow from an FCI ST51 in-line gas flow meter (Photo 11) was recorded each minute to the SCADA system. King Island personnel also collected this information and commented on the cover inflation and the colour of the flame during twice weekly sampling.

The biogas pressure under the CAL cover was measured by Yokogawa pressure transducer (Photo 12) and was logged on the SCADA system.

Photo 11: Inline FCI biogas flow meter

Photo 12: Pressure transducer

3.3.2 Biogas Characterisation

The methane content of the biogas was measured by the inline Draeger Polytron 500 methane analyser (Photo 13) situated downstream of the biogas fan. Readings were automatically logged on the SCADA system.

Photo 13: Draeger methane analyser

The Odour Unit performed further field and laboratory analysis of the biogas on 5, 6th June 2012. All biogas samples were collected from a suitable tap point on the fan discharge of the gas flare system (Photo 14). Samples were collected during periods of flare burning. A variety of analytical methods were employed:

- A LANDTEC GEM 2000 Plus Portable Gas Analyser allowed continuous in-situ monitoring of methane, carbon dioxide, oxygen, hydrogen and hydrogen sulphide. This unit was connected and measuring between 4:06pm to 5:24pm on the 5th June and 7:25am to 11:44am on the 6th June.

- Gastec detector tubes measured hydrogen sulphide, ammonia, benzene in aromatic hydrocarbons and carbon dioxide at various times on the 6th June 2012.

- GCMS laboratory analysis was performed on two biogas samples collected in Tedlar bags at 8:00am and 11:55 am on the 6th June 2012. Constituents analysed included: methane, carbon dioxide, oxygen, ammonia, BTEX, hydrogen sulphide and volatile fatty acids.

Photo 14: Gas flare system with LANDTEC GEM Portable Analyser connected to biogas sampling point

3.4 Sludge & Crust Analysis

3.4.1 Sludge

Sludge accumulation in the CAL was checked on February 9th and again on 5th June 2012 by Dr Mike Johns of Johns Environmental using a Royce 711 TSS meter inserted through the two inspection points located near the centreline of the CAL cover.

On 5th June 2012, a sludge truck connected through a 2 inch camlock fitting to the HDPE sludge pipework recovered 10 m^3 of sludge from the CAL to test the effectiveness of the sludge removal system. Samples of the sludge were collected evenly over the period of sludge withdrawal and analysed by EML(Chem) for Total Solids, Volatile Solids, TP, TN and TDS.

3.4.2 Crust

Crust accumulation was assessed using the inspection ports on February 9th and again on 5th June 2012. The assessment involved quantitative measurement of crust depth at the two inspection ports. Crust samples were collected from each port on the 5th June and analysed by EML(Chem) for total Solids, Volatile Solids, TN, TP and Oil and Grease.

A physical assessment by walking on the cover was also conducted to determine if noticeable build up was occurring under the cover.

4 Start-up Dynamics

Monitoring the start-up of the anaerobic process in the King Island CAL provided useful data for future prediction of industrial green field sites.

4.1 Biogas production

Evidence of biogas production was found 30 days after the CAL start-up. The biogas pressure under the CAL cover, shown in Figure 2, lifted from zero on the 11th of January. JBS Personnel also noticed inflation of the CAL cover from the 12th of January.

Due to delays in commissioning the flare operation, the biogas pressure slowly increased over the subsequent 12 days and reached a steady pressure of ~30Pa. Additional biogas was most likely to have been vented from the safety vents at higher pressures.

Once the biogas flare was commissioned on the 2nd February, the pressure at the end of each day was dependant on the daily flowrate through the flare. After a day of reasonable flow the pressure decreased, while on a day of low or zero biogas flow the pressure increased.

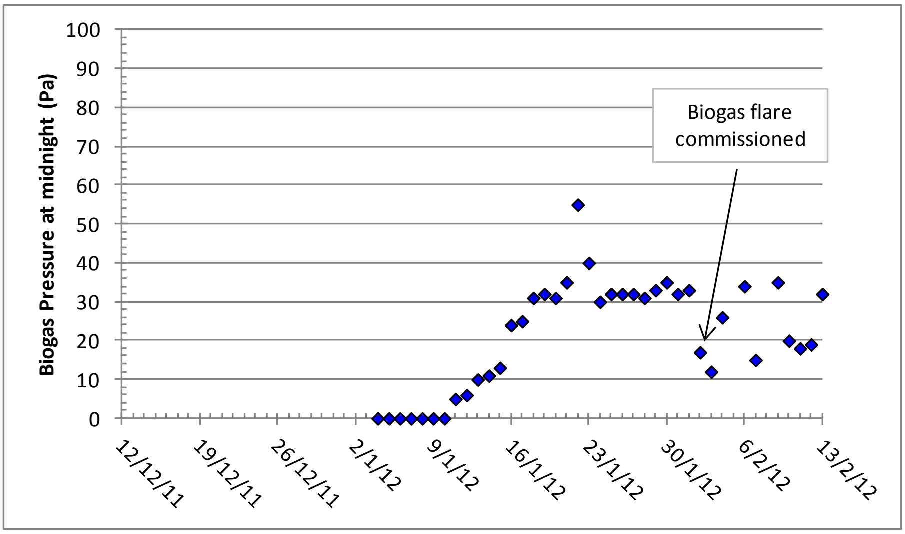


Figure 2: Biogas pressure under the CAL cover (at midnight)

The lag in biogas production of approximately one month during the CAL start-up indicates the biogas flare commissioning is not possible at the same time as pond commissioning. If biogas is to be used for boiler fuel or electricity generation there will be a delay in the reliable feed of biogas.

Summary Comment 1: Biogas production is not immediate with CAL commissioning

4.2 Start up period

The start-up period of a CAL is determined by the time required to achieve a stable anaerobic microorganism population. In simple terms, successful anaerobic treatment occurs when the two anaerobic microbial populations; acidogenic and methanogenic, are simultaneously thriving. The overall anaerobic process is simplified in Figure 3.

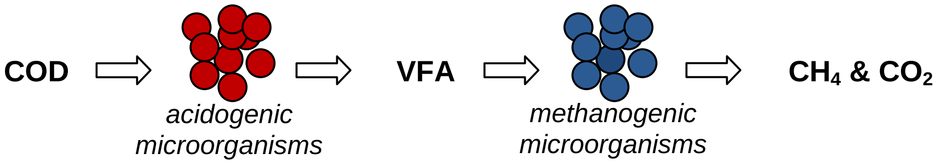


Figure 3: Overall anaerobic process

4.2.1 Acidogen start-up period

The first biological process involves *acidogenic* microorganisms breaking down complex organic material into volatile fatty acids (VFAs) and other short chain organic molecules. .

Acidogens develop a stable population more quickly than the methanogenic population as they are faster growing and less sensitive to environmental conditions. The result of the growing acidogen population in the absence of a thriving methanogen population is the following.

1. Increased volatile fatty acid (VFA) concentration.

   VFAs are an intermediate product of acidogenic activity. They are the food for the methanogens. When acidogenic activity exceeds methanogenic activity, VFAs will accumulate in the CAL effluent. Figure 4 shows an increasing concentration of volatile fatty acids in the CAL outlet at start-up, peaking on the 5th January. This shows evidence of acidogen presence at start-up and their rapid growth which outpace the methanogenic growth.

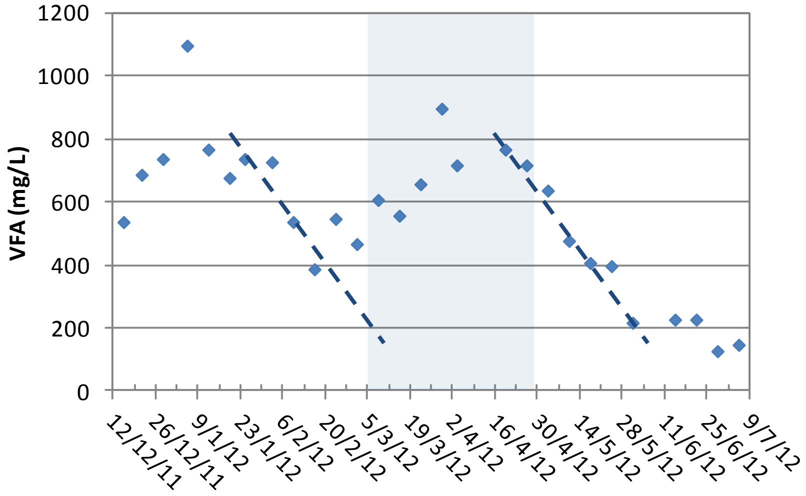


Figure 4: Volatile Fatty acid concentration over monitoring period

2. Increased ammonia concentration.

Ammonia is the formed from the cleaving of organic nitrogen during the breakdown of the long chain organic molecules in the acidogenic first phase of the anaerobic process. Figure 5 shows a significantly greater ammonia concentration in the CAL outlet than the CAL inlet on each day while Figure 6 shows little change in total nitrogen across the pond. Figure 7 shows that the percentage of nitrogen present as ammonia reached a value of 83% by 28th December 2011 and has remained at that value since. This confirms the initial presence of acidogens and their rapid growth at start-up.

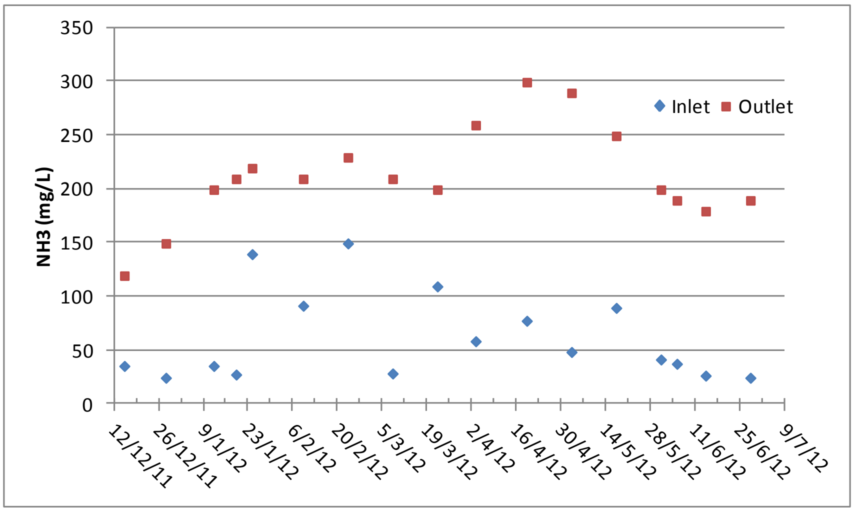


Figure 5: Ammonia concentration over monitoring period

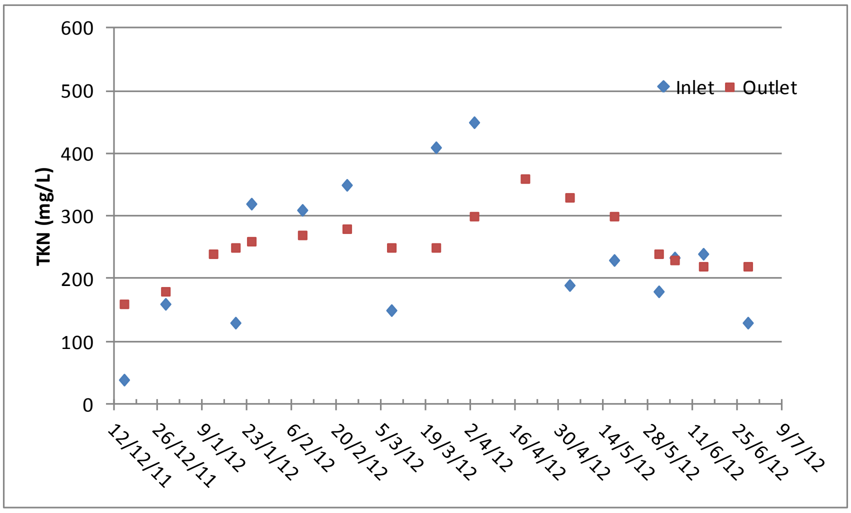


Figure 6: Total nitrogen concentration over monitoring period

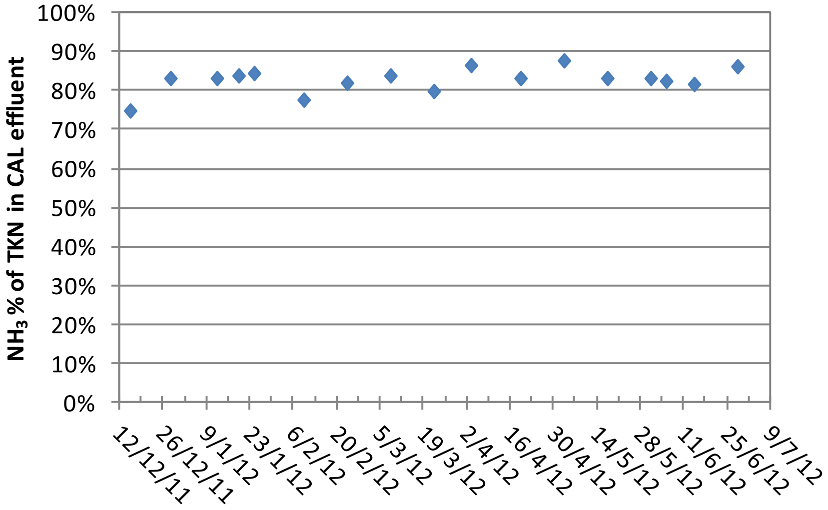


Figure 7: Ammonia percentage of total nitrogen

3. Decreased pH.

Since the volatile fatty acids are intermediate products in the microbial reactions, they increase in concentration when their production (acidogenc stage) exceeds consumption (methanogenic stage). This lowers the pH in the CAL. However, for meat processing effluent, the ammonia released during protein degradation buffers this increase in acidity and there is often little change in pH.

Figure 8 shows the CAL effluent pH decreasing sharply from 7.0 to 6.3 in the initial 2 weeks of startup. The pH then hovers between 6.3 and 6.5 until the 24th January 2012 and then slowly rises towards neutral over the remaining 5 months. This is a relatively small change in pH compared to many other types of effluent.

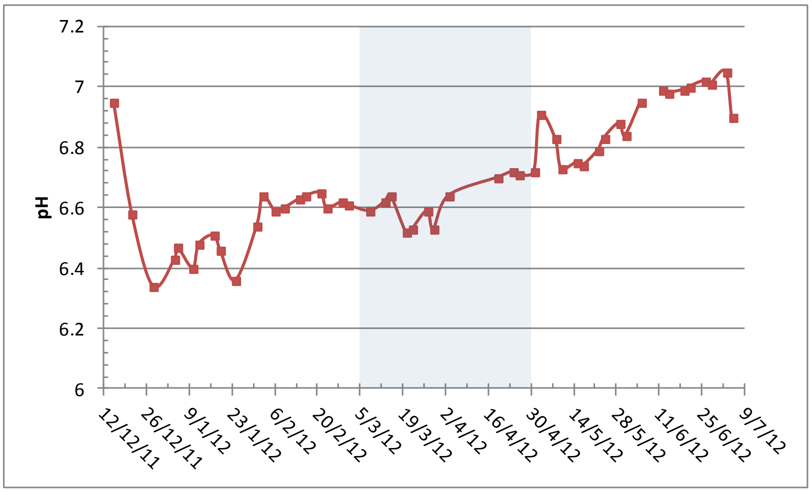


Figure 8: pH over monitoring period

The acidogen population appear to develop a stable population by the 28th December as evidenced by the ammonia concentration. This suggests rapid start-up period for the acidogens.

4.2.2 Methanogen start-up period

The second biological process involves methanogenic microorganism converting the VFA and other short chain molecules into the predominant final gaseous products of methane and carbon dioxide. A perturbation from 5th March to 30th April 2012, discussed in Section 4.3, appeared to retard the development of the methanogenic population. However the eventual formation of a stable methanogenic population was displayed by the following.

1. Low VFA concentration.
   As the overall anaerobic process proceeds to completeness, the VFA concentration decreases as it is consumed by the methanogens. Figure 4 shows the VFA slowly dropping from the 5th January as the rate of VFA consumption by the methanogens exceeds the production by the acidogens.

   In the absence of the perturbation the VFA concentration probably would have dropped to a stable number within 3 months of commissioning.

2. Increased pH towards neutral.
   The methanogens consume the volatile fatty acids for methane production, which removes acidic products from the CAL. Figure 8 shows an increasing pH trend from the 24th January.

3. Increased total alkalinity.
   The carbon dioxide formed mainly in the methanogenic stage drives the total alkalinity higher. The total alkalinity shown in Figure 9 is highly variable during the start-up period. Like pH, the alkalinity is affected by many competing reactions.

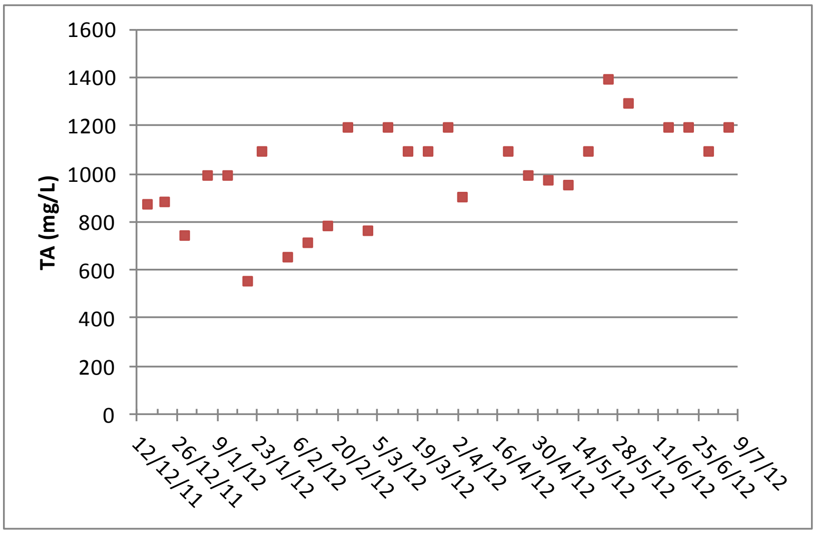


Figure 9: Total alkalinity concentration over the monitoring period

4. Increased biogas production.
   Unlike the acidogens, whose main products are soluble COD such as acetic acid, the products of methanogenic activity are gases – methane and carbon dioxide. Consequently, significant biogas generation is a sign of methanogen health. Biogas production began by the 11th January when the pressure under the pond, shown in Figure 2, started increasing. Upon flare commission the biogas flowrate was measured and Figure 10 shows it consistently increasing until the 5th March. In the absence of the perturbation, the biogas flow may have stabilised much earlier.

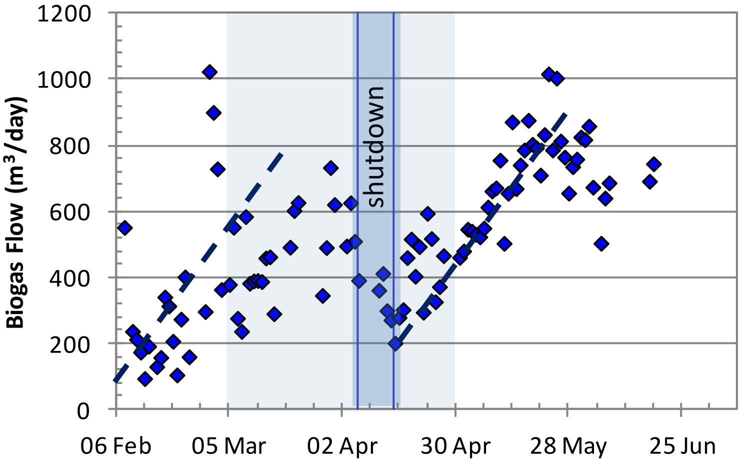


Figure 10: Daily biogas flow over monitoring period

5. Decreased effluent COD
   The formation of methane and carbon dioxide by the methanogens removes the COD in the liquid phase thus reducing COD concentration in the effluent stream. Figure 11 shows COD in the outlet stream was significantly reduced compared to the influent during the first 3 months. Initially, this reduction in COD is due to dilution of the influent by the low strength water initially present in the pond (used to aid covering). Subsequent reduction is increasingly due to anaerobic action (until the perturbation in early March).

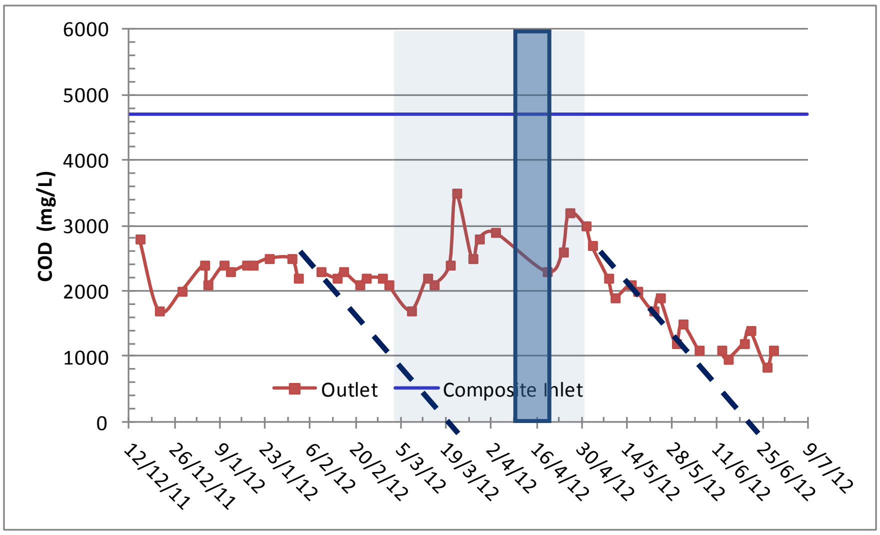


Figure 11: COD over monitoring period

Summary comment 2 The start-up period for the acidogenic microbes was approximately 2 weeks from commissioning. This is indicated by the organic nitrogen conversion to ammonia and supported by VFA concentration and pH.

Summary comment 3 In the absence of the perturbation starting on the 5th March the start-up period for the methanogenic microbes was probably of the order of 3 months from commissioning.

4.3 Influence of shocks (perturbations)

Two major shocks were experienced by the bacterial population in the CAL during the start-up period:

1. A sudden and sustained conductivity increase, shown in Figure 12, adversely affected the population for two months from the early March to early May 2012.

2. A 10 day programmed plant shutdown from 6th to 15th April 2012.

These periods are represented by the light and dark blue shaded regions respectively on Figure 10 to Figure 13.

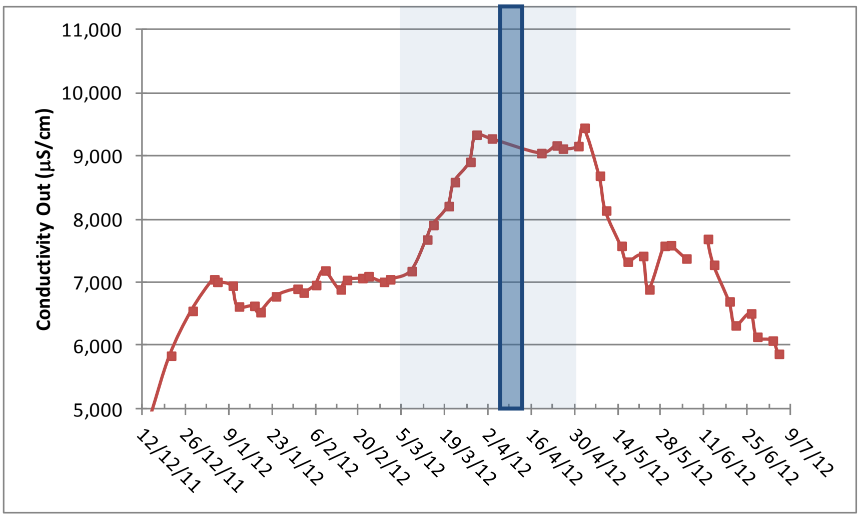


Figure 12: Effluent Conductivity over monitoring period

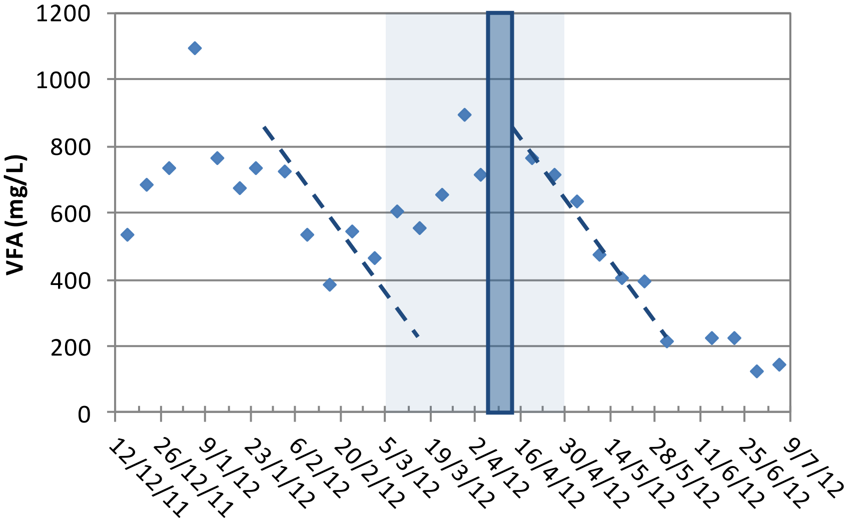


Figure 13: VFA concentration over monitoring period

A rapid decline in anaerobic performance occurred with the conductivity shock. Although methanogenic biological populations are relatively hardy in respect of salt, they are highly sensitive during the start-up period when they are present in low numbers and not yet adapted to adverse environmental conditions. The onset of the conductivity spike caused immediate inhibition of methanogenic activity as evidenced by increase in VFA and COD concentration and decrease in the biogas production.

The unplanned shutdown provided time for the anaerobic process to recuperate during this period of high conductivity. COD in the effluent decreased while there was no new feed material. However the rate of biogas production also decreased due to the lack of cod-rich influent to the pond.

The methanogens acclimatised to the design conductivity levels as predicted by the Johns Environmental design team. Once the conductivity in the CAL returned to normal levels (in mid May), CAL performance began to stabilise. Sudden changes in environmental conditions or feed composition are known to be detrimental to anaerobic performance.

Summary comment 4 Anaerobic processes are highly sensitive to rapid changes in the CAL environment or feed composition during start-up.

4.4 Microbial Stress Indicators

Stress to the methanogens causes decreased anaerobic performance. Common stressors are start-up, changing or adverse environmental conditions and shock loads in the feed. An indication of CAL health is useful to allow mitigation before complete failure occurs. Traditionally, pH measurement is used for this purpose. Unfortunately, this is unreliable for protein-rich wastewater.

Besides biogas production, the best indicator of CAL health is the volatile fatty acid (VFA) to total alkalinity (TA) ratio. Typically, when this ratio is less than 0.25, the anaerobic population is stress-free and performing optimally.

Figure 14 shows the VFA/TA ratio over the entire monitoring period. The stress associated with start up is clearly seen as a rapid increase in the VFA/TA ratio to a peak of 1.2 during startup. Subsequently in late January and early February, as the methanogen population builds, the VFA/TA ratio falls to more moderate – but still high – levels. The high conductivity shock caused the VFA/TA ratio to increase again from early March. Eventually with acclimatisation and lowering conductivity, the VFA/TA ratio stabilised below the optimum 0.25 value.

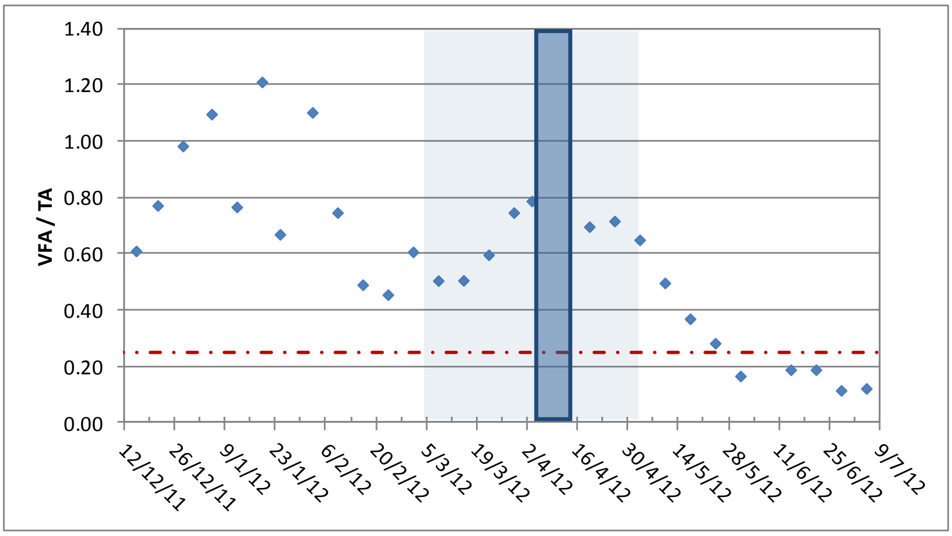


Figure 14: VFA/TA ratio over the CAL monitoring period

*Summary comment 5***:** VFA/TA ratio is a much more sensitive indication of the CAL health than pH or COD removals and gives a good insight into CAL performance, especially if biogas data is unavailable.

4.5 Pond Temperature

Pond temperature is a critical parameter since it strongly affects the rate of microbial activity. For some ponds it is challenging to get them to temperature quickly – especially in southern or highland regions of Australia. The CAL feed temperature is the main driver in determining the operating temperature. However, the daily air temperature clearly also has an influence, particularly in the absence of a thick insulating crust.

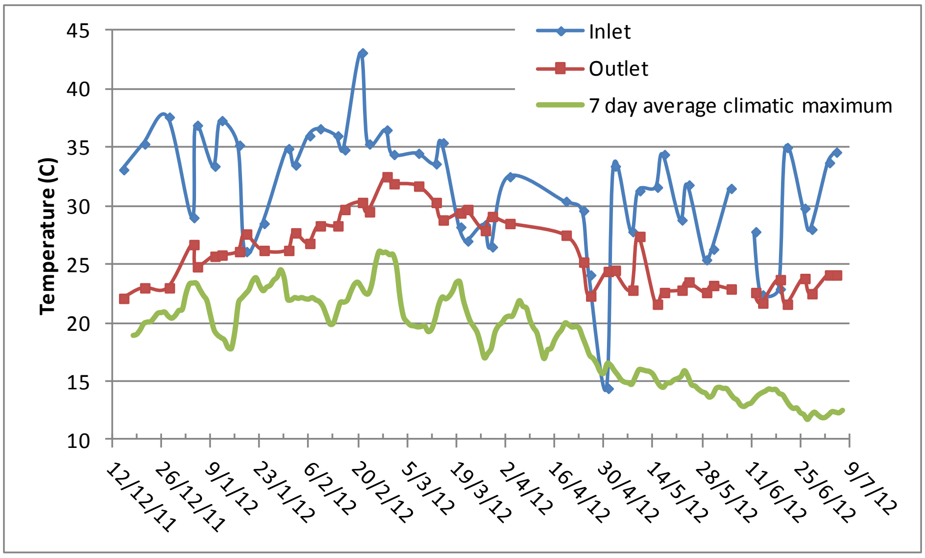


Figure 15: Temperature of the CAL over the monitoring period

Figure 15 shows that even during summer, the increase in CAL temperature is slow. During winter, the CAL temperature stabilised at 23°C even during the windy, wet conditions which characterise winter on King Island.

Summary comment 6 CAL temperature is influenced by both the temperature inlet of the influent stream and the climatic conditions. Warming of the CAL volume is slow.

5 Normal Operating Performance

Normal operating performance within the design specifications for the CAL was achieved by the end of the monitoring period. This section presents and interprets measured information during this period, which occurred from approximately mid May until the end of the project in early July 2012.

5.1 Biogas production

Biogas flowrate and composition have been monitored since flare commissioning.

5.1.1 Biogas flowrate

The daily biogas flow was collected over the monitoring period when the flare was operational. The full data set is presented in Appendix C. Figure 16 (reproduced from Figure 10 in Section 4.2.2) shows the daily biogas flow over the monitoring period and highlights the following:

1. Stable biogas production in this CAL is approximately 740m^3/day. This is higher than the expected design value of 600m^3/day (25 CMH), probably due to elevated wastewater flows into the CAL.
2. The biogas production increased with improved CAL performance, especially as conductivity reduced after the shock load.
3. The biogas flow is relatively steady over the 7-day week, despite the 5 day production cycle. Biogas flow was only seen to significantly decrease when raw feed was stopped for a longer period of time as seen during the 10 day shutdown.
4. The maximum biogas production was 1,100 m^3/d requiring 20.4 hours of flare operation at its high flare setting (45 CMH). This translates to a 50% peaking factor.

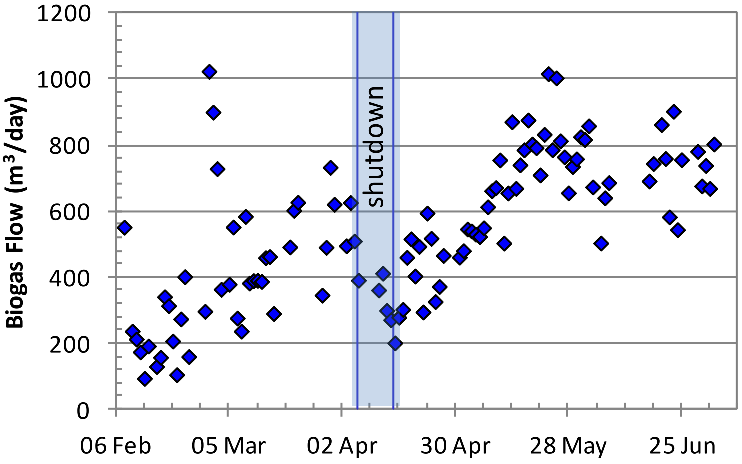


Figure 16: Biogas flow over monitoring period

Summary comment 7: Biogas flowrate increases during start-up and is affected by adverse conditions in the pond.

Summary comment 8: The maximum gas production observed is 1,100 m^3/d representing a peaking factor of 50%.

Summary comment 9: Biogas production is relatively constant during the week, despite the 5 day operating profile.

5.1.2 Biogas methane composition

The methane content of the biogas was measured using the online methane analyser during flare operation. The data is presented in Figure 17. The candlestick format represents the range between the daily 90%ile and 10%ile values. The 50 percentile is also indicated since late April. The full data set is presented in Appendix C. The following is inferred from Figure 17:

1. Biogas methane concentration varied between 66% and 76% v/v when operating under normal operation conditions. The median biogas methane concentration since May is 70% v/v which is the design value.
2. Methane concentration slowly increased as the CAL performance improved.
3. The methane concentration of the biogas is significantly reduced by the onset of the conductivity shock. It is unclear if this was a true reflection of the reduced performance in the CAL or onset of inaccurate measurements caused by a worsening moisture condensation issue in the online methane analyser (as discussed below). However, shocks are well known to reduce the methane content of biogas.
4. The biogas was enriched in methane (up to 78%) near the end of the shutdown period.

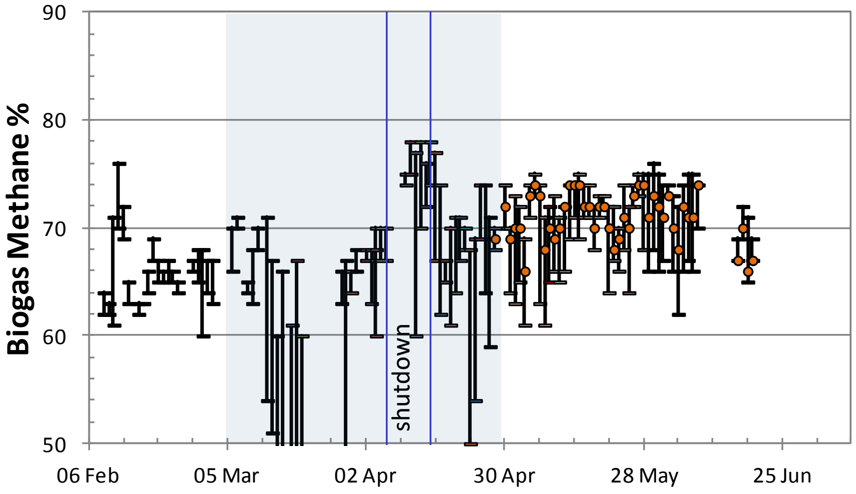


Figure 17: Biogas methane concentration

Methane analysers are known to be affected by the high moisture content of biogas. To check this issue, a portable analyser fitted with an inline filter to remove moisture was used to monitor biogas methane in June sampling conducted by The Odour Unit during periods of flare operation. Figure 18 shows that the portable analyser consistently returning a slightly higher value for the methane concentration compared to the on-line analyser (ranging between 1% to 3%v/v absolute). Hence the on-line analyser methane measurements can be considered conservative.

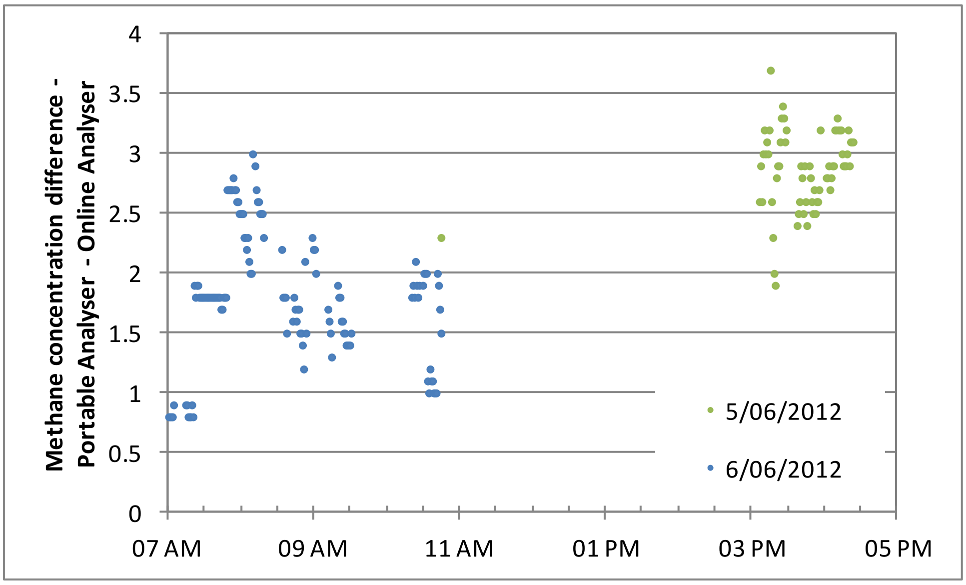


Figure 18: Difference in methane analysis between portable analyser and on-line analyser

The methane concentration of the biogas consistently decreased during production hours. Figure 19 shows methane concentrations during a typical production day. In contrast, there was a reasonably steady methane concentration on non-production days (Figure 20). The graphs for all other days are presented in Appendix C. This effect is not due to moisture affecting the meter as the portable biogas analyser also detected the same effect (Figure 21).

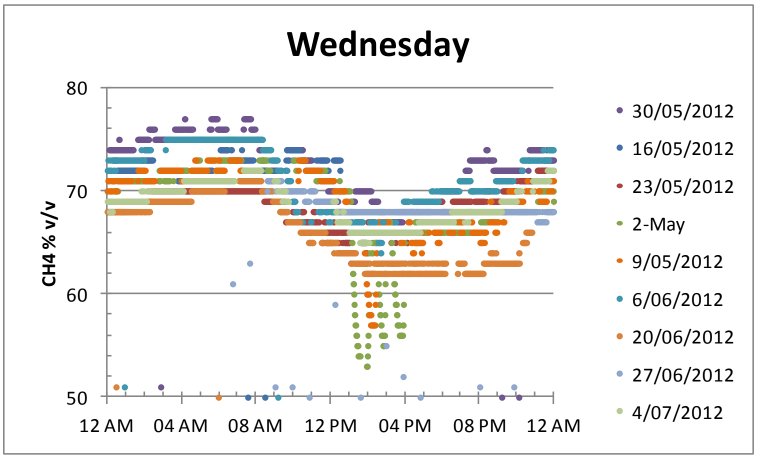


Figure 19: Methane concentration over production day

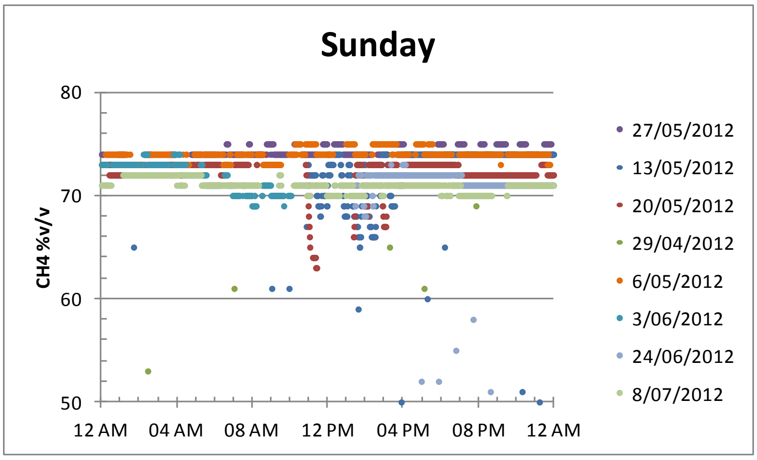


Figure 20: Methane concentration over non-production day

Summary Comment 10: Methane concentration increased during start-up. The median methane concentration of the biogas is 71%v/v during normal operation with a range of ± 5% absolute.

5.1.3 Biogas composition – other components

The composition of the biogas during a normal operating day is presented in Table 3 from the various analytical methods used by The Odour Unit from sampling performed on-site in June 2012. GCMS laboratory analysis of samples collected in Tedlar bags provided concentration data for the main gases and other trace impurities. The full set of results is presented in Appendix C.

The primary components are methane and CO_2. Some air is also present (oxygen & nitrogen). Trace concentrations of hydrogen sulphide, BTEX and acetic acid were also detected.

Table 3: Comparison of results from various biogas analysis techniques

Test Item		unit	On-line analyser	Portable analyser	Gastec Tubes	Tedlar
CH_4	8am	%	76	75.6		59.6
	12pm		68	69.7		45.6
CO_2	8am	%		24	24	29.1
	12pm			23.4		23.6
O_2	8am	%		0		2.4
	12pm			0.8		6.6
Balance (N_2 and Ar)	8am	%		0.2		9
	12pm			6.1		24.3
H_2S	8am	ppm			1500	2749
	12pm			90	110	254

The methane concentrations found by the laboratory analysis of biogas collected in Tedlar bags are very different to those found by the other measurement devices. The reason for this difference is unclear.

The presence of oxygen during production hours as shown in Figure 21, suggests the entrainment of air in the feed stream to the CAL during production hours as there is no other oxygen source. The feed stream is aerated over the rotating screen immediately prior to its feed to the CAL. Calculations suggest that as little as 0.13ppm of dissolved air entrained in the feed stream is sufficient to contribute the levels of oxygen and nitrogen gas measured in the biogas (Figure 21).

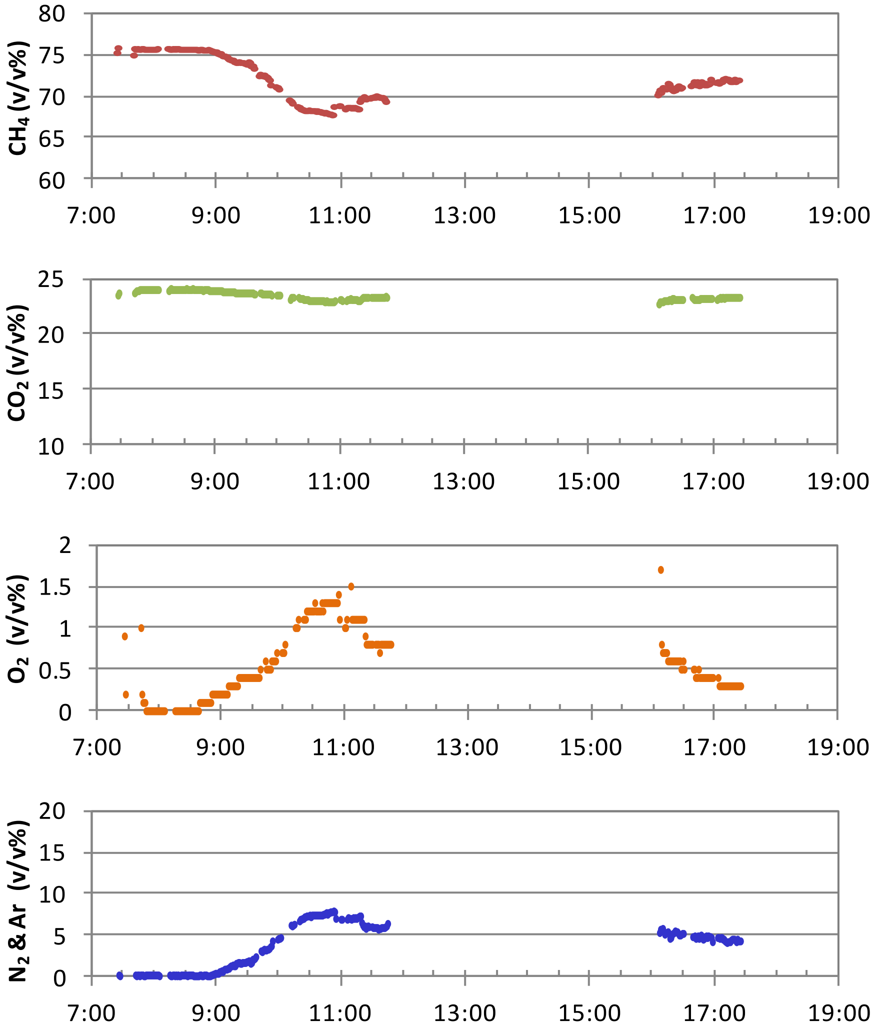


Figure 21: Biogas composition analysed by portable meter over production day

Hydrogen sulphide concentration in the biogas ranged between 70 ppm and 2,000 ppm as shown in Figure 22 and Photo 15. A rapid decline in the level of hydrogen sulphide in biogas was detected by all measuring devices once processing of animals commenced. These are relatively low levels of H_2S.

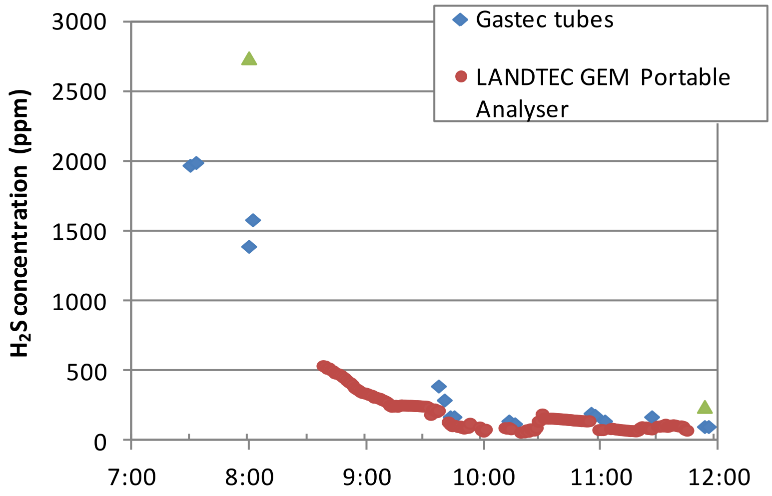


Figure 22: Hydrogen Sulphide concentration in biogas

Photo 15: Hydrogen Sulphide Gastec tubes collected over morning of 6th June 2012

Summary comment 11: Hydrogen sulphide levels in the biogas were low and fell at the onset of production.

5.2 Contaminant Removal from the Wastewater

5.2.1 Influent Composition

Contaminant removal was calculated as the inlet concentration minus the outlet concentration divided by the inlet concentration. While obtaining accurate CAL outlet concentration is straightforward, due to the long HRT of the CAL which dampens fluctuations in composition, it was much more difficult to obtain a consistent and representative composition of the feed to the CAL since:

- There is usually little equalisation of the raw wastewater prior to the CAL;
- A number of waste sources of widely varying composition contribute intermittently to the feed, so it has an inherently high variability;
- The raw wastewater is made up of TSS (which tend to settle), greases (which tend to float) and other components which are dissolved in the water.

Figure 23 and Figure 24 show the variation of measured components in the raw inlet stream over the 8-month monitoring period. All samples were collected as composite of 3 grabs collected over 15 minutes during peak production hours and the full set of values is presented in Appendix C.

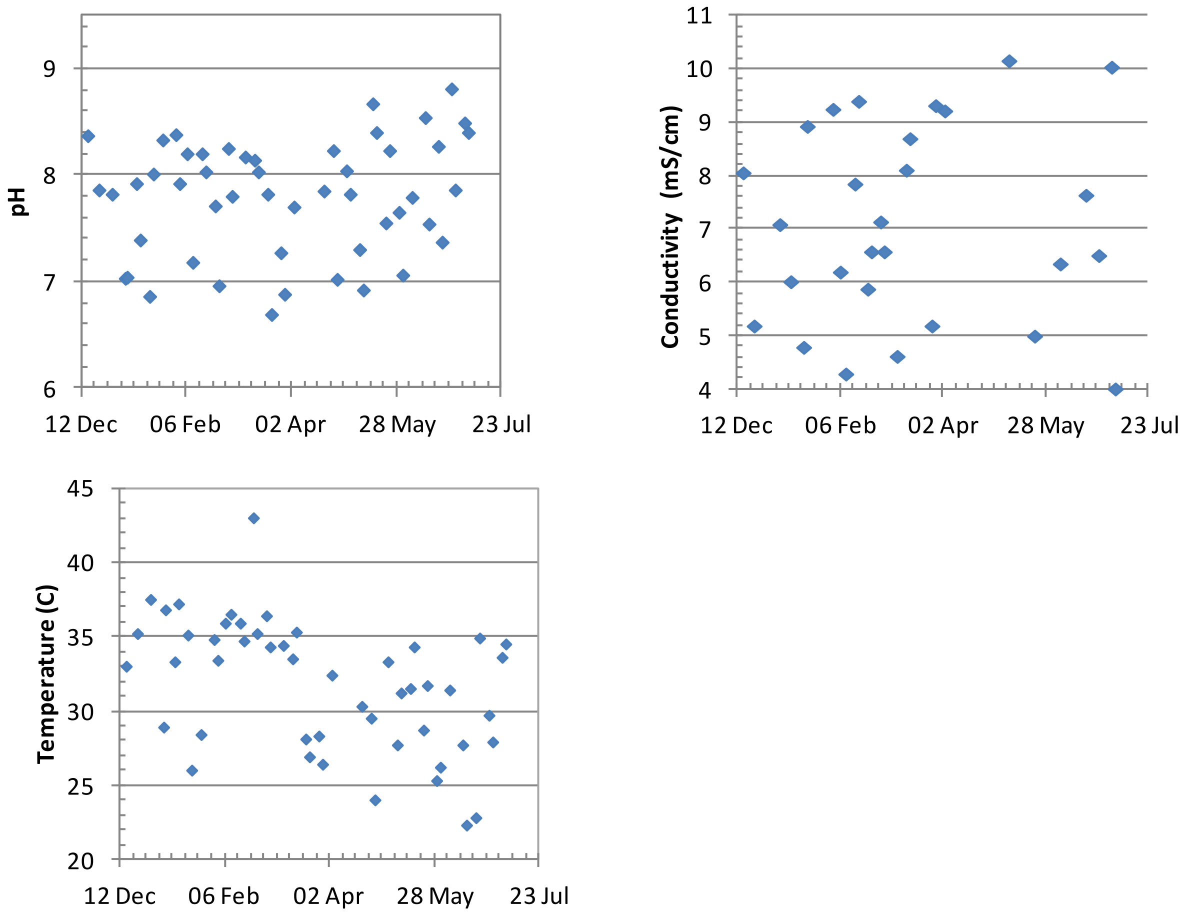


Figure 23: Field Results of Composite Inlet Stream over 7 month Monitoring Period

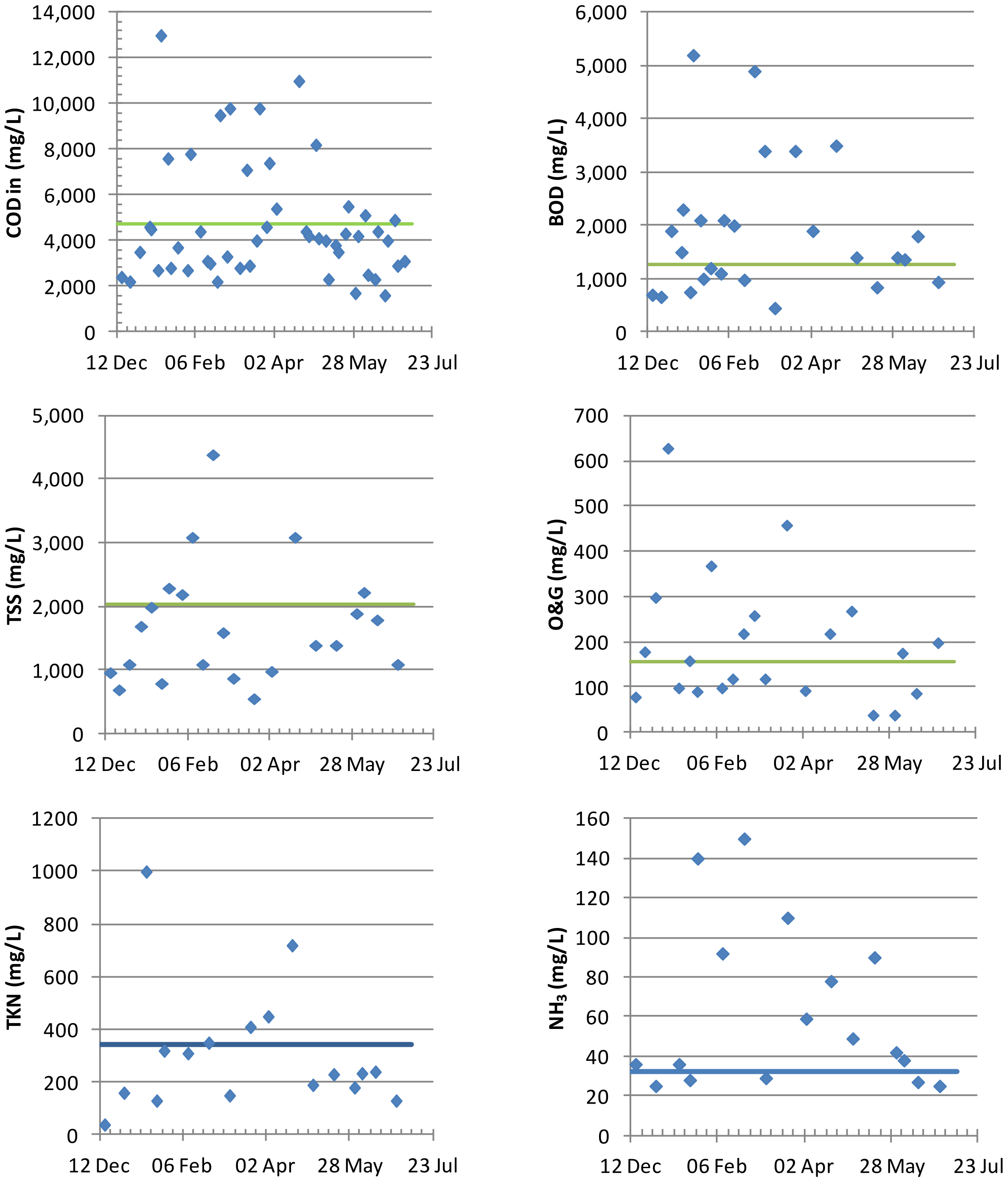


Figure 24: Laboratory Results of Composite Inlet Stream over 7 month Monitoring Period

In June 2012, grab samples of the CAL feed were collected over a typical production day and analysed individually to assess the degree of daily variation. The wide variation in raw effluent composition (Figure 25) and flow (Figure 26) over the production day highlights the complexity in obtaining “accurate” values for the overall load to the CAL.

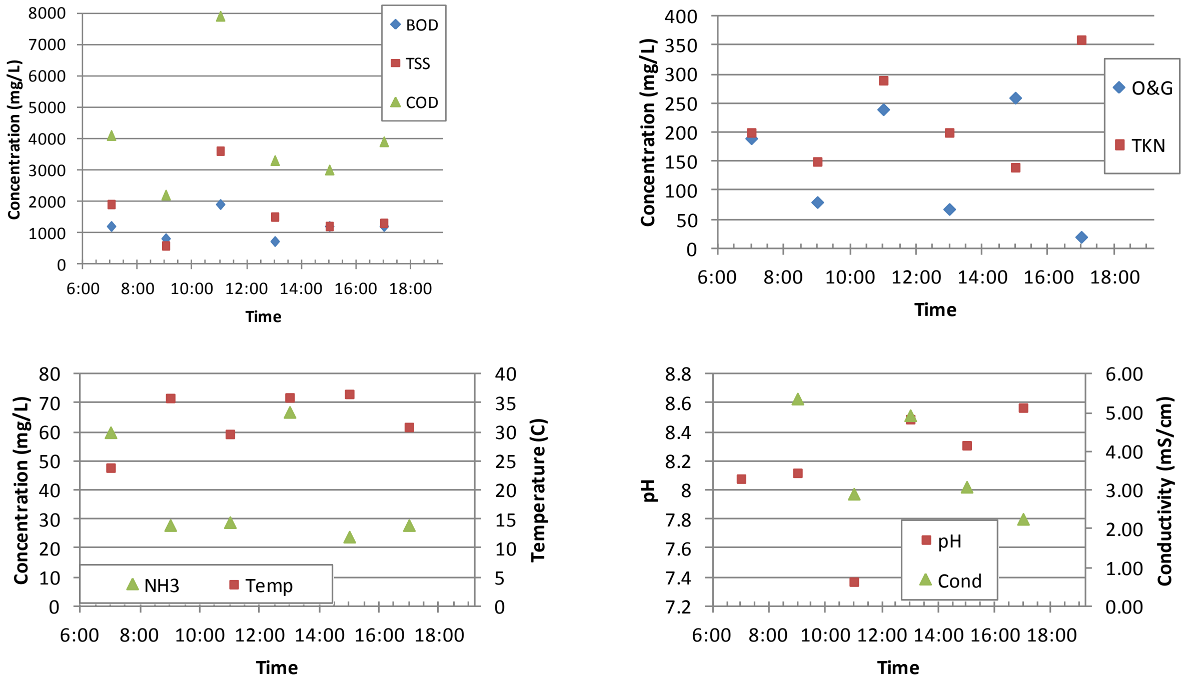


Figure 25: Raw Effluent Composition across Typical Production Day

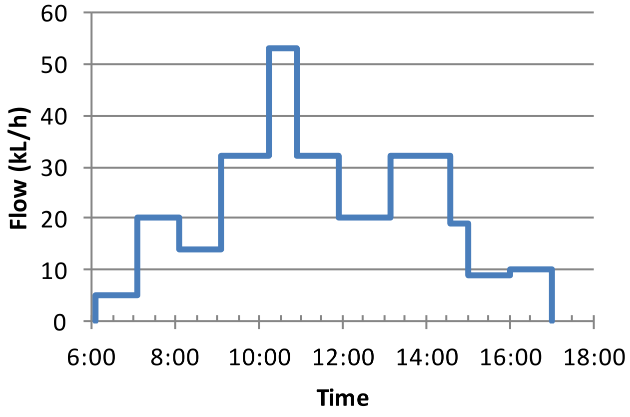


Figure 26: Raw Effluent Flow across Typical Production Day

Table 4 summarises the influent compositions determined by a range of methods. These results show the wide variation in feed composition and the difficulty in determining the raw feed composition to the CAL with high precision.

Table 4: Composite Samples of Raw Feed to CAL

Parameter		**Design**	**Composite 9th Feb 12** (Note 1)	**Composite 4th June 12**	**Composite 5th June 12**	**Median over monitoring period** (Note 2)	**Weighted composite 5th June** (Note 3)
COD	mg/L	7,250	7,700	5,200	3,500	4,050	4,724
BOD	mg/L	3,000	3,800	1,400	1,300	1,450	1,265
TSS	mg/L	2,000	4,900	2,200	1,400	1,500	2,023
O&G	mg/L	120	420	110	190	170	156
EC	uS/cm	8,500	8,800		6,000	8,100	5,671
pH		7.2	7	7.8	7.6	7.9	7.9
Temperature	°C	30-35			30.9	33	32.4
NH_3	mg/L	250	76	77	41	42	39
NO_2	mg/L				<1		
NO_3	mg/L				<0.02		
TKN	mg/L		340	270	210	230	227
TN	mg/L	450			210		
TP	mg/L	45			23		

Notes:
1. The three composite samples were created from equal volume grab samples collected over the production day.
2. The median value was calculated from the influent samples collected twice weekly over the monitoring period.
3. The weighted composite value is calculated from the sum of the 2 hourly loads divided by the total volume using samples collected on the 5th June 2012

The overall raw feed composition used to calculate removal rates used the weighted composite values in Table 4. These values are reasonably close to the three composites and the median values found over the monitoring period.

The weighted composite used is differs from the design composition with BOD, COD and EC being significantly lower and the O&G being reasonably greater.

Summary Comment 12: Raw effluent composition is difficult to determine and high accuracy is unattainable due to daily variation.

5.2.2 COD and BOD_5 removal by the CAL

The COD and BOD removal rates were initially stable during start-up, decreased as a result of the conductivity shock but stabilised once normal operation was achieved. The data from the period of normal CAL operation shows 85% BOD and 80% COD removal, which match the CAL design values. Removal is shown visually in Photo 16. The CAL appears to perform similarly to an uncovered anaerobic pond at similar operating regimes.

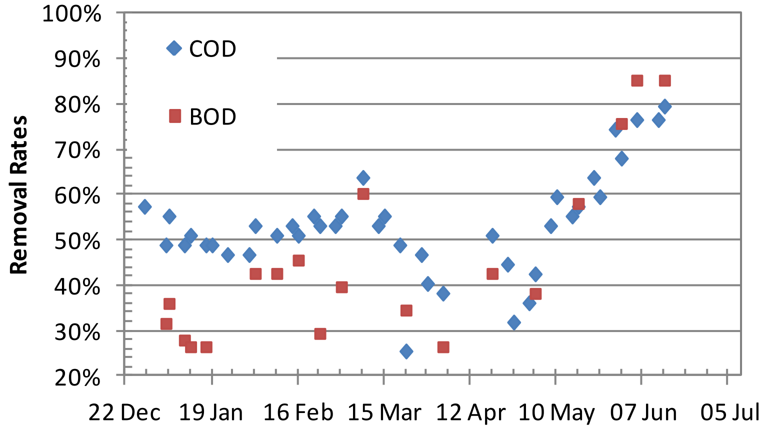


Figure 27: COD concentrations over the CAL monitoring period

Photo 16: CAL Feed and Discharge

Summary comment 13: BOD and COD removal stabilised at 85 and 80% removal respectively by the end of the monitoring period.

5.2.3 TSS and Oil & Grease Removal

Figure 28 shows total suspended solids and oil & grease removals were excellent from start-up with removals quickly achieving of 85% and 80% respectively. Some of this may be due to settling and/or crusting under the cover – a factor to be discussed in Section 6.

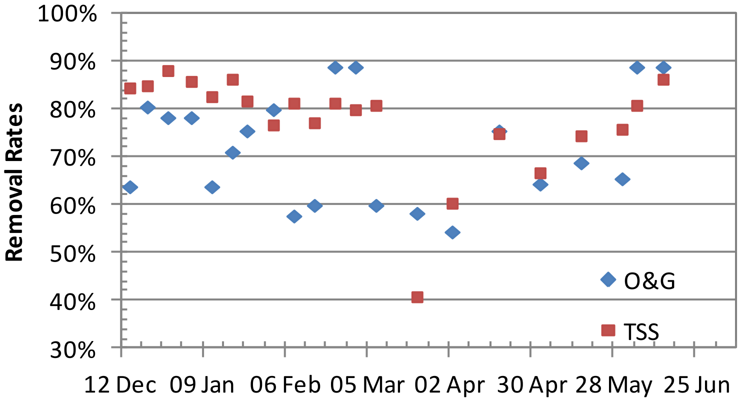


Figure 28: TSS and O&G removal over the CAL monitoring period

Summary comment 14: TSS and O&G removal was immediate from startup and is approximately 80% for both

5.2.4 Feed Flow

Figure 29 presents the wastewater flow and production numbers over the monitoring period. Both increased from late February and have remained approximately constant through to the end of the monitoring period. The median wastewater flow from late February is 350kL/d production day flow which exceeds the 290kL/d design flow by a considerable margin.

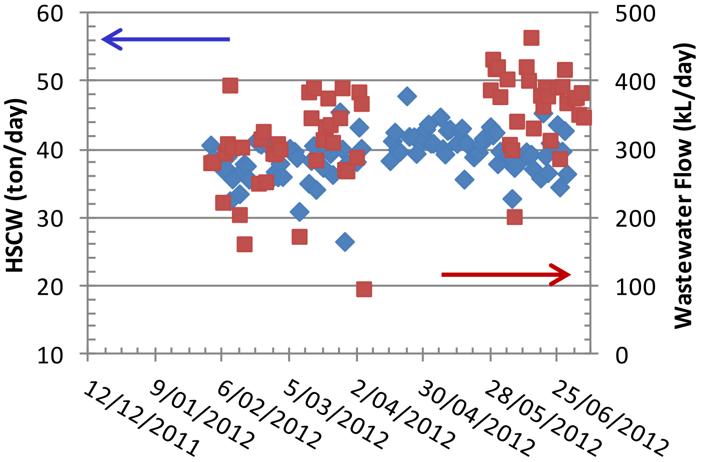


Figure 29: Daily Wastewater Flows and Production

5.3 Estimate of Biogas Production

The volume of biogas formed from the COD removed (biogas conversion factor) is an useful metric for estimating biogas production in CALs. Typical values in the literature are 0.5 m^3 biogas per kg COD removed for a stably operating anaerobic system.

Figure 30 presents calculated results using the weekly biogas production, the weekly average outlet COD concentration, the weighted composite inlet COD concentration (Section 5.2.1) and the weekly wastewater flow. The two data points highlighted in red are thought to be outliers:

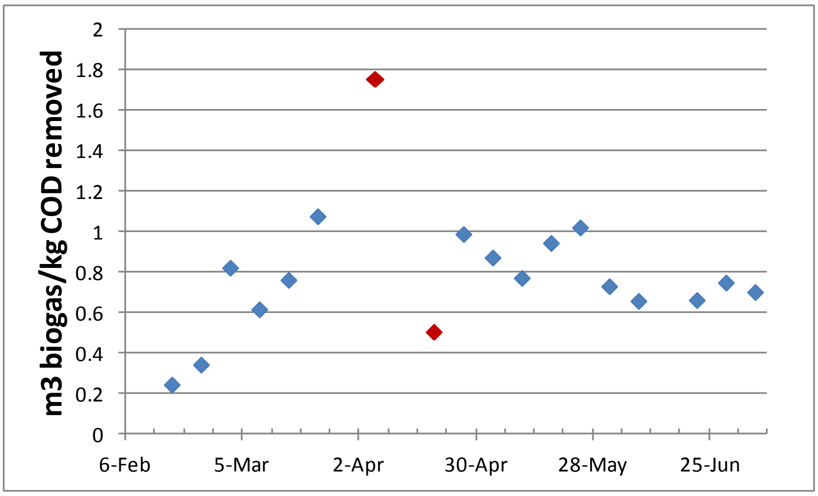


Figure 30: Biogas production per kg COD removed

Initially the biogas conversion factor increased gradually from 0.25 m^3/kg COD removed while the anaerobic biology builds to a stable population.

The biogas production rate stabilised during normal operation at approximately 0.7 m^3 biogas/kg COD removed. At the median biogas methane concentration of 70% v/v this is equivalent to 0.5 m^3 CH_4/kg COD removed. This value is significantly higher than literature values and should be used with caution due to the challenges in determining incoming COD levels.

Summary comment 15: The biogas conversion rate is 0.7 m^3 biogas/kg COD removed or 0.5 m^3 methane/kg COD removed.

6 Crust & Solids accumulation

Uncovered anaerobic ponds treating meat processing wastewater form often thick crusts over time due to the buoyant nature of the fine suspended solids in the wastewater and the tendency of oil & grease to separate into a floating scum. This is undesirable for CALs since the floating crust poses a risk to the integrity of the cover and the biogas capture system.

Settled solids also pose a risk to the longevity of the CAL, since they can rapidly accumulate and fill the pond, reducing the HRT available for treatment. The solids arise from two sources:

- Inert suspended and gross solids originally present in the raw wastewater. Levels of these solids need to be reduced through effective pre-treatment;
- Biological solids formed during the anaerobic process. Although anaerobic processes are renown for their low sludge formation per tonne COD removed, large amounts of solids are still formed due to the high inlet organic load these ponds typically receive. Poor design can lead to rapid sludge build-up. CAL designs differ in how they handle this issue.

Pre-treatment of the raw wastewater at King Island consisted of a rotating wedgewire screen to remove gross and suspended solids. The original Dissolved Air Flotation (DAF) plant at King Island was badly corroded and JBS decided oil & grease levels were sufficiently low in the raw wastewater to avoid the need for a new DAF.

Crust build-up and sludge accumulation was investigated during the project after 2 and 6 months of operation.

6.1 Crust Build-up

An accumulation of a semi-solid floating scum under the cover was noted during the project. Table 5 reviews the visual observations through the two sample ports at the two inspection dates. Analysis of the scum sample from June 2012 is presented in Appendix C.

Within 2 months of commissioning, a substantial thickness of a thick mustard brown scum was evident at both sample ports (Photo 17 and Photo 18). At the screen (inlet) end of the CAL, the scum had hardened off in the port . However, it remained soft, but firm under the cover.

Table 5: Crust build-up observed in the two inspection ports

	Feb 2012	June 2012
Flare end	150 mm moussy crust	< 50 mm moussy crust
Screen end	200 mm mousse	>200 mm crust with fine paunch solids

After 6 months of operation the scum was evident under the cover for the first 9 meters distance from the inlet end. A sample found that it comprised 13% w/w total solids containing

25% w/w oil and grease on a dry basis. This is consistent with a fatty deposit separating from the influent stream.

Photo 17: CAL crust at flare end

Photo 18: CAL crust at screen end

In the outlet half of the CAL, the crust had thinned considerably since February and had a thin, mousse-like consistency. It is likely that much of the scum arises from a foamy mousse formed when the bacteria are under stress during the first 3 months of operation. As the pond has recovered and settled into normal operation, this scum will probably disappear – as is evident in the June sampling.

Nearer the inlet, however, there appears to be an issue with scum accumulation. The quantity of fat deposited over a 6 month period can be estimated from the median O&G influent concentration of 156mg/L, and assuming an O&G removal of 80% (see Figure 28) and flowrate of 350 kL/d. The remaining O&G translates to 5.6 tonnes of potential scum.

Summary Comment 16: Undesirable crust build-up is occurring beneath the cover with greater than 200mm of semi-firm crust present within the inlet third of the CAL.

6.2 Sludge Accumulation

Sludge depth was measured using the Royce TSS meter calibrated to measure TSS levels. Sludge levels approximating greater than 1% w/v (e.g. 10,000 mg/l TSS) are detected when the unit goes off scale.

The sludge in the CAL has increased within the first 6 months of the CAL operation as shown in Table 6. The first 3 months saw a sludge depth of approximately 2 m increasing to 2.7m within the next 3 months. However, at both points, the Royce probe was able to easily transit through the sludge layer to the CAL base indicating that sludge was largely biological. Interpreting this finding is difficult since Johns Environmental has only recently applied this technology to CALs. Some sludge is essential to the normal operation of the pond, however, excessive quantities are undesirable. Further assessment is needed to determine this.

Table 6: Sludge depth off the CAL base observed in the two inspection ports

	Feb 2012	June 2012
Flare end	2.25m	2.7m
Screen end	2m	2.7m

During the June 2012 sampling, a sludge truck successfully withdrew 10 m^3 of black sludge through the sludge pipework over 15 minutes (Photo 19). There was little indication of rat holing (breakthrough of liquid) during the pumping since analysis of sludge sampled at even intervals during the withdrawal process showed little decrease in total solids with 2.7, 2.4, 2.4 and 2.2% total solids in sequential samples. Further analytical results are presented in Appendix C.

Photo 19: Sludge truck

Summary Comment 17: Sludge accumulation was evident in the CAL over 6 months of operation but was successfully withdrawn through the sludge removal piping.

7 Conclusions

The major outcomes highlighted by this CAL monitoring study are presented below.

1. The CAL has operated successfully for 25 weeks post startup with excellent COD removal (80 %) which is the primary function of the pond, despite higher than design wastewater flows. The CAL delivers excellent biogas quality and quantity after 6 months of operation. Biogas production is approximately 0.7 m^3/kg of COD removed or 740 m^3/day. The biogas methane concentration is consistently greater than 70% v/v.

2. Gas flow is reasonably steady over the full 7 day week despite the facility operating a 5 day/week.

3. Methane and CO_2 are the main biogas constituents with lesser contaminants including nitrogen, argon, oxygen and H_2S. H_2S levels were typically 100 to 200 ppm during the production day, but as a concentration as high as 2,000 ppm (0.2%) was measured early in the production day.

4. CAL start-up required 25 weeks for stable operation. Initial startup was successful within 8 weeks, despite the site being a greenfield site with no option for sludge inoculation.

5. A shock load of salt near the end phase of start-up severely upset the CAL with noticeable impact on biogas production, VFA and alkalinity values and COD removal. This highlights the need for careful control of raw wastewater composition where a reliable and consistent supply of biogas is needed – for example for boiler fuel, or cogeneration in a gas engine.

6. The VFA/TA ratio proved an effective way of following the performance of the CAL but is subject to time effective analysis.

7. Crust build up has occurred under the cover possibly due to the relatively low level of pretreatment used at King Island. The initial phase may be more due to microbial foaming than oil & grease accumulation and shows signs of thinning in the rear half of the CAL as it achieves normal performance. Near the inlet, however the scum is rich in oil & grease.

8. Sludge has also accumulated in the base of the CAL, but may be part of the treatment process. A significant volume was successfully extracted using the sludge removal pipework after 6 months.

8 Recommendations

1. The King Island CAL is operating at design performance and is producing sizeable volumes of methane rich biogas. The technology appears eminently appropriate for red meat processing plants.

2. There is a need for attentive management of raw wastewater feed composition and variation compared to the traditional uncovered anaerobic ponds to ensure a reliable and steady supply of biogas for end-use. This will be financially important where biogas is recovered for gas engine cogeneration or for use as boiler fuel.

3. The risk of crust accumulation under the cover is clearly demonstrated at King Island. This issue merits further attention to develop means by which potential damage to infrastructure is avoided.

4. Sludge withdrawal systems are recommended as a sludge management tool for CALs.

5. The degree of error in methane concentration measured by in-line analysers caused by biogas moisture is unclear. There were large discrepancies in methane content measured by inline, portable and laboratory methane analysis. It would be helpful to quantify the impact of moisture on inline analysis for this critical measurement.

6. While pretreatment reduces the risk of crust build-up and sludge accumulation, it also reduces potential for biogas formation with the lowered organic load. Recommended further research on the optimal degree of pretreatment would determine maximum biogas production while not hindering CAL performance.

7. Stormwater removal from the cover is a persistent problem in industrial CAL operation. Attention to this detail in CAL cover design would benefit industry greatly.

8. Appendices

Appendix A: Monitoring Plan

This document proposes a plan [The Plan] for a 9-month investigation of the CAL operation. The Plan seeks to obtain sufficient factual information to achieve the stated objective.

Key Elements

The Plan will require the following field investigations to be conducted:

1. Characterisation of the volume and quality of effluent entering and leaving the CAL.
2. Characterisation of the volume and quality of the biogas leaving the CAL.
3. Sludge volumes produced and the utility of the sludge removal system in removing them.

Management of the Investigation

The skills required to perform the investigation require several contractors and consultants to be involved. The separate tasks and people involved are presented in Table 1.

Dr. Mike Johns of Johns Environmental [JEPL] will be project manager for the investigation and assist in on-site field work and training the Swift Australia King Island [SAKI] persons responsible for sampling and maintenance of the field equipment.

Dr Bronwen Butler (Johns Environmental) will assist in the investigation. She will collate, process and validate the field data supplied by and generate deliverables and communicate with SAKI personnel.

SAKI personnel will be responsible for monitoring and/or recording:

- Daily flows to the CAL;
- Inlet and outlet wastewater sampling (after training by Drs Johns and Butler);
- Daily biogas flows;
- Daily biogas composition (on-line methane analyser);
- Plant data as required.

These data will be sent electronically to Johns Environmental in Brisbane for collation and processing.

Table 7 – Tasks & Responsibilities

Task	Entity
Wastewater Treatment	
Create sampling schedule	JEPL
Installation of in-line flow-meter	SAKI
Collect CAL flow data	SAKI
Wastewater measurements using HACH HQ 40d	SAKI
Collection of scheduled inlet and outlet CAL wastewater samples	SAKI
Send data to JEPL	SAKI
Analysis of wastewater samples	EML (Chem) Pty Ltd
Collation of results	JEPL
Biogas Production	
Installation of in-line biogas flow meter	SAKI
Installation of methane analyser	SAKI
Collect biogas flow data	SAKI
Collect methane analyser data	SAKI
Collection of biogas sample	The Odour Unit
Analysis of biogas sample	The Odour Unit
Send data to JEPL	SAKI
Collation of biogas results	JEPL
Sludge and Crust Accumulation	
Check sludge and crust accumulation	JEPL

-

Wastewater

Wastewater Flow

A Siemens magflow meter will be installed on the raw wastewater rising main from pump station 1 to the Doda screen upstream of the CAL. This ensures measurements are taken in a flooded section of pipe. The flowmeter allows both instantaneous and totalized flow recording.

The daily raw wastewater flows entering the CAL will be recorded and downloaded to JEPL on a weekly basis. JEPL also request the daily HSCW production information.

Wastewater Characterisation

Readily accessible sampling points will be installed at the inlet and outlet of the CAL.

Wastewater sampling across the CAL will be as follows. Composite is the preferred sampling technique due to the variability in composition experienced from abattoirs.

1. Field measurements of the effluent discharged from the CAL will determine pH, temperature, DO, conductivity and ORP by SAKI personnel using a portable Hach HQ40d device supplied by JEPL. This sampling will be conducted twice per week or as instructed by JEPL. JEPL request that the visual appearance and odour of the effluent also be noted.

2. Composite wastewater samples of the raw wastewater and CAL discharge will be taken by SAKI personnel using the schedules provided in **Error! Reference source not found.** and Table 10 for the start-up period and Table 11 for normal operation. JEPL will inform the SAKI personnel as to when to change to the next schedule. The schedule details will be subject to change by JEPL if conditions warrant. A suitable 25 mm dia. tap has been provided for pre-CAL sampling at pump station 1 and safe access will be provided for sampling the CAL discharge in the downstream pit.

3. Where possible, samples will go to the testing laboratory without chemical preservation to provide the best description of components. JEPL will inform SAKI personnel in writing with amendments to the sampling schedule.

Table 8– Parameters to be measured by HACH HQ40d

	Parameter	**H1**
HACH HQ40d measurements	pH	✔
	Temperature	✔
	Conductivity	✔
	Oxidation Reduction Potential	✔

Table 9– Parameters to be measured by laboratory analysis

	Parameter	**S1**	**S2**	**S3**	**S4**	**S5**
Samples for laboratory analysis	pH	✓	✓	✓		
	Total Chemical Oxygen Demand (COD)t	✓	✓	✓		
	5-day Biological Oxygen Demand (BOD_5)		✓	✓		
	Oil & grease (O&G)			✓		
	Total Suspended Solids (TSS)			✓		
	Volatile Fatty Acids (VFA)				✓	
	Total Alkalinity (TA)				✓	
	Ammonia-nitrogen (NH_3-N)					✓
	Total Kjeldahl Nitrogen (TKN)					✓

Table 10 – Start-up Operation Sampling Schedule

Week	Tues		Thurs	
	CAL inlet	CAL outlet	CAL inlet	CAL outlet
a	**H1** **S2**	**H1** **S2**	**H1** **S3**	**H1** **S3, S4**
b	**H1** **S2**	**H1** **S2**	**H1** **S3, S5**	**H1** **S3, S4, S5**

Table 11 – Normal Operation Sampling Schedule

Week	Tues		Thurs	
	CAL inlet	CAL outlet	CAL inlet	CAL outlet
a	**H1** **S1**	**H1** **S1**	**H1** **S1**	**H1** **S1, S4**
b	**H1** **S1**	**H1** **S1**	**H1** **S3, S5**	**H1** **S3, S4, S5**

Biogas Monitoring

Biogas Flow

The biogas train will be equipped with a FCI in-line gas flow meters. The SAKI personnel will collect this information and should also comment on the cover inflation and the colour of the flame. JEPL request for the information to be forwarded weekly.

Biogas Characterisation

Biogas quality will be characterised. Methane content is the most critical component of the biogas in terms of end use. Off-line sampling permits contaminant levels in the gas to be known – these determine the extent of clean up required for specific uses.

1. The in-line methane analysis data will be collected by SAKI personnel from the Draeger unit installed.

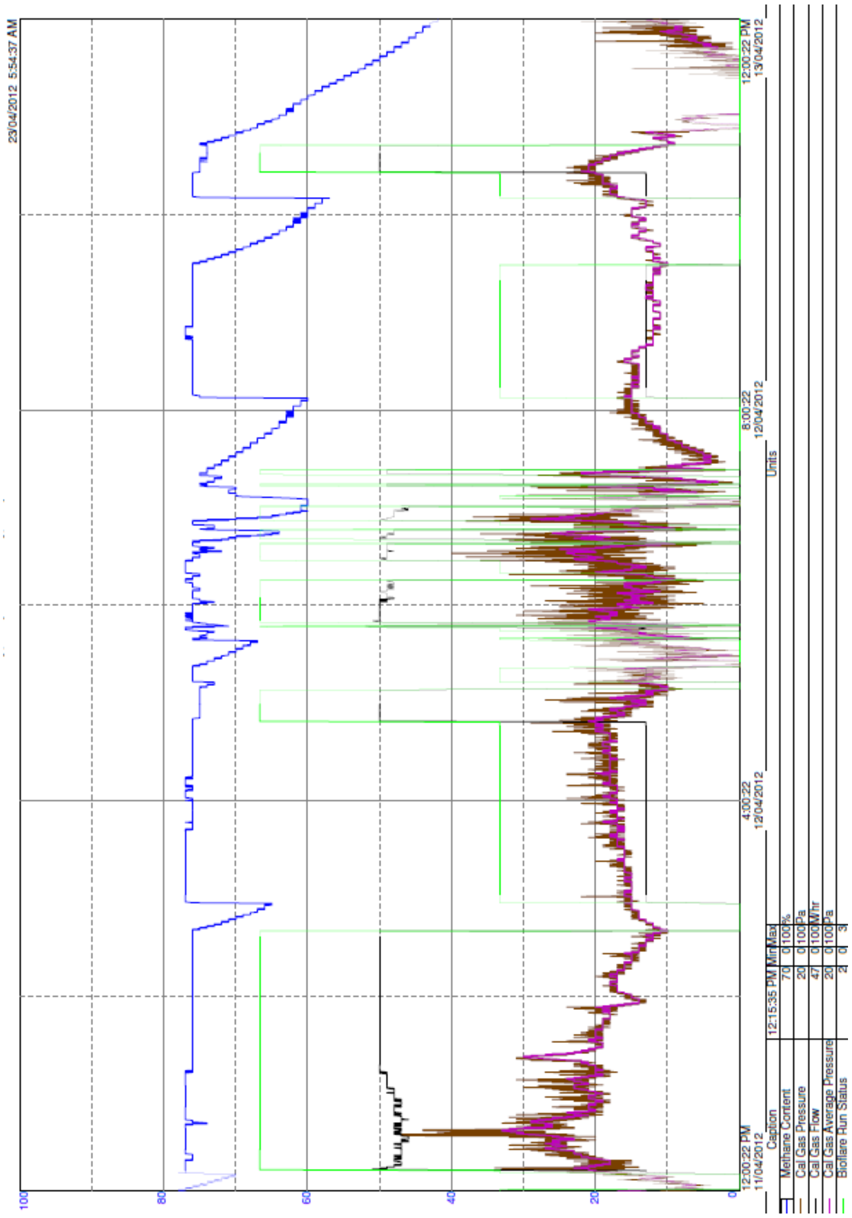
2. Biogas samples will be taken by The Odour Unit during normal operation period to analyse the biogas for CH_3, CO_2, H_2S, NH_3, N_2O and CO content to permit comparison with data from sites involved in the A.ENV.0093 biogas quality study. The Odour Unit will analyse the samples using on-site equipment.

Sludge and Crust Accumulation

Crusting under the HDPE cover is highly undesirable. The development of crust will be assayed by inspection at access points in the cover. This will be performed by Dr Johns over the normal operation period when he is on site.

Sludge accumulation is also undesirable in the CAL. Sludge removal pipes have been installed on the floor of the CAL. These allow periodic sludge removal if necessary. Towards the end of the normal operation trial period Dr Johns will inspect the CAL to determine if sludge accumulation has occurred using both a Hydrolab Minisonde, a Royce meter and by pumping from the sludge collection system. An estimate of sludge accumulation will be made.

Appendix B: Sample SCADA Biogas Output



Appendix C – Raw data

Table 12: Daily Biogas Pressure at Midnight

Date	Biogas Pressure (Pa)	Date	Biogas Pressure (Pa)
4/1/12	0	**25/1/12**	32
5/1/12	0	**26/1/12**	32
6/1/12	0	**27/1/12**	32
7/1/12	0	**28/1/12**	31
8/1/12	0	**29/1/12**	33
9/1/12	0	**30/1/12**	35
10/1/12	0	**31/1/12**	32
11/1/12	5	**1/2/12**	33
12/1/12	6	**2/2/12**	17
13/1/12	10	**3/2/12**	12
14/1/12	11	**4/2/12**	26
15/1/12	13	**5/2/12**	
16/1/12	24	**6/2/12**	34
17/1/12	25	**7/2/12**	15
18/1/12	31	**8/2/12**	
19/1/12	32	**9/2/12**	35
20/1/12	31	**10/2/12**	20
21/1/12	35	**11/2/12**	18
22/1/12	55	**12/2/12**	19
23/1/12	40	**13/2/12**	32
24/1/12	30	14/2/12	39

Table 13: CAL Feed - Field Analysis

Date	Time	pH	Temp °C	Cond µS/cm	O.R.P. mV
15/12/2011	10:09	8.38	33.1	8,070	-80.7
21/12/2011	8:35	7.87	35.3	5,200	-51
28/12/2011	8:55	7.83	37.6	3,220	-49.1
4/01/2012	10:10	7.04	29	7,100	-1
5/01/2012	8:20	7.05	36.9	19,660	-1.4
10/01/2012	8:50	7.93	33.4	6,030	-54.4
12/01/2012	10:30	7.4	37.3	3,050	-21.7
17/01/2012	7:55	6.87	35.2	4,800	9
19/01/2012	8.37	8.02	26.1	8,940	-60.2
24/01/2012	8:10	8.34	28.5	14,200	-77.4
31/01/2012	8:30	8.39	34.9	15,950	-82.2
2/02/2012	8:04	7.93	33.5	9,260	-57.2
6/02/2012	11:00	8.21	36	6210	-73
9/02/2012	10:30	7.19	36.6	4300	
14/02/2012	8:45	8.21	36	7860	-72
16/02/2012	8:30	8.04	34.8	9410	-61
21/02/2012	10:30	7.72	43.1	5890	-43
23/02/2012	8:45	6.97	35.3	6590	3
28/02/2012	8:32	8.26	36.5	7150	-74
1/03/2012	8:30	7.81	34.4	6590	-47
8/03/2012		8.18	34.5	4630	-69
13/03/2012	8:35	8.15	33.6	8120	-67
15/03/2012	8:45	8.04	35.4	8710	-61
20/03/2012	10:50	7.83	28.2	16850	-47
22/03/2012	7:40	6.7	27	21730	19
27/03/2012	8:30	7.28	28.4	5200	-15
29/03/2012	10:45	6.89	26.5	9330	8
3/04/2012	7:35	7.71	32.5	9230	-43
19/04/2012	15:15	7.86	30.4	2600	-51
24/04/2012		8.24	29.6	28,300	-72
26/04/2012	7:50	7.03	24.1	3120	0
1/05/2012	8:30	8.05	14.4	11,410	-58
3/05/2012	7:45	7.83	33.4	25000	-48
8/05/2012	8:36	7.31	27.8	10170	-17
10/05/2012	12:00	6.93	31.3	3540	5
15/05/2012	7:50	8.68	31.6	13300	-99
17/05/2012	7:50	8.41	34.4	12650	-83
22/05/2012	13:26	7.56	28.8	5010	32
24/05/2012	8:15	8.24	31.8	30900	-72
29/05/2012	8:15	7.66	25.4	21010	-38
31/05/2012	8:20	7.07	26.3	11350	-3
5/06/2012	9:30	7.8	31.5	6363	
12/06/2012	8:05	8.55	27.8	18900	-80
14/06/2012	9:35	7.55	22.4	3410	-33
19/06/2012	8:00	8.28	22.9	7650	-63
21/06/2012	8:15	7.38	35	24200	-13
26/06/2012	10:45	8.82	29.8	6520	-96
28/06/2012	7:40	7.87	28	21150	-41
3/07/2012	8:15	8.5	33.7	10050	-79
5/07/2012	10:40	8.41	34.6	4020	-73

Table 14: CAL Discharge - Field Analysis

Date	pH	Temp °C	Cond µS/cm	O.R.P. mV
15/12/2011	6.95	22.1	4,910	4.5
21/12/2011	6.58	23	5,840	25.6
28/12/2011	6.34	23	6,550	39.3
4/01/2012	6.43	26.7	7,050	34.6
5/01/2012	6.47	24.8	7,010	32.4
10/01/2012	6.4	25.7	6,950	36.5
12/01/2012	6.48	25.8	6,620	31.7
17/01/2012	6.51	26.1	6,630	29.8
19/01/2012	6.46	27.6	6,530	32.9
24/01/2012	6.36	26.2	6,780	38.9
31/01/2012	6.54	26.2	6,900	28.1
2/02/2012	6.64	27.7	6,840	22.6
6/02/2012	6.59	26.8	6960	25
9/02/2012	6.6	28.3	7190	25
14/02/2012	6.63	28.3	6890	23
16/02/2012	6.64	29.7	7040	23
21/02/2012	6.65	30.3	7070	22
23/02/2012	6.6	29.5	7100	25
28/02/2012	6.62	32.5	7010	24
1/03/2012	6.61	31.9	7050	25
8/03/2012	6.59	31.7	7180	26
13/03/2012	6.62	30.3	7680	24
15/03/2012	6.64	28.8	7910	23
20/03/2012	6.52	29.4	8210	30
22/03/2012	6.53	29.7	8590	29
27/03/2012	6.59	27.9	8910	25
29/03/2012	6.53	29.1	9340	29
3/04/2012	6.64	28.5	9280	23
19/04/2012	6.7	27.5	9050	19
24/04/2012	6.72	25.2	9170	18
26/04/2012	6.71	22.3	9120	18
1/05/2012	6.72	24.4	9160	18
3/05/2012	6.91	24.5	9450	7
8/05/2012	6.83	22.8	8690	11
10/05/2012	6.73	27.4	8140	17
15/05/2012	6.75	21.6	7580	16
17/05/2012	6.74	22.6	7330	15
22/05/2012	6.79	22.8	7420	14
24/05/2012	6.83	23.5	6890	11
29/05/2012	6.88	22.6	7580	8
31/05/2012	6.84	23.2	7590	11
5/06/2012	6.95	22.9	7380	12
12/06/2012	6.99	22.6	7690	10
14/06/2012	6.98	21.7	7280	10
19/06/2012	6.99	23.7	6700	10
21/06/2012	7	21.6	6320	9
26/06/2012	7.02	23.8	6510	8
28/06/2012	7.01	22.5	6140	9
3/07/2012	7.05	24.1	6080	6
5/07/2012	6.9	24.1	5870	15

Table 15: CAL Feed – Laboratory Analysis

Date	COD (mg/L)	BOD_5 (mg/L)	O&G (mg/L)	TSS (mg/L)	NH_3 as N (mg/L)	TKN as N (mg/L)
15/12/2011	2,400	700	80	970	36	39
21/12/2011	2,200	660	180	700		
28/12/2011	3,500	1,900	300	1100	25	160
4/01/2012	4,600	1,500				
5/01/2012	4,500	2,300	630	1700		
10/01/2012	2,700	750				
12/01/2012	13,000	5,200	100	2000	36	1000
17/01/2012	7,600	2,100				
19/01/2012	2,800	1,000	160	800	28	130
24/01/2012	3,700	1,200	92	2300	140	320
31/01/2012	2,700	1,100				
2/02/2012	7,800	2,100	370	2200		
9/02/2012	4400	2,000	100	3100	92	310
14/02/2012	3100					
16/02/2012	3000	980	120	1100		
21/02/2012	2200					
23/02/2012	9500	4,900	220	4400	150	350
28/02/2012	3300					
1/03/2012	9800	3,400	260	1600		
8/03/2012	2800	450	120	880	29	150
13/03/2012	7100					
15/03/2012	2900					
20/03/2012	4000					
22/03/2012	9800	3,400	460	560	110	410
27/03/2012	4600					
29/03/2012	7400					
3/04/2012	5400	1,900	94	990	59	450
19/04/2012	11000	3,500	220	3100	78	720
24/04/2012	4400					
26/04/2012	4200					
1/05/2012	8200					
3/05/2012	4100	1,400	270	1400	49	190
8/05/2012	4000					
10/05/2012	2300					
15/05/2012	3800					
17/05/2012	3500	840	40	1400	90	230
22/05/2012	4300					
24/05/2012	5500					
29/05/2012	1700					
31/05/2012	4200	1,400	40	1900	42	180
5/06/2012	5112	1,364	177	2233	38	234
7/06/2012	2500					
12/06/2012	2300					
14/06/2012	4400	1,800	88	1800	27	240
19/06/2012	1600					
21/06/2012	4000					
26/06/2012	4900					
28/06/2012	2900	940	200	1100	25	130
3/07/2012	3100					
5/07/2012	2400	660	110	1100	73	180

Table 16: CAL Discharge – Laboratory Analysis

Date	COD (mg/L)	BOD$_5$ (mg/L)	O&G (mg/L)	TSS (mg/L)	NH$_3$ as N (mg/L)	TKN as N (mg/L)	VFA (mg/L)	TA as CaCO$_3$ (mg/L)
15/12/2011	2800	780	65	340	120	160	540	880
21/12/2011	1700	720	35	330			690	890
28/12/2011	2000	1100	39	260	150	180	740	750
4/01/2012	2400	930						
5/01/2012	2100	870	39	310			1100	1000
10/01/2012	2400	980						
12/01/2012	2300	1000	65	380	200	240	770	1000
17/01/2012	2400	1000						
19/01/2012	2400	1600	52	300	210	250	680	560
24/01/2012	2500	1400	44	400	220	260	740	1100
31/01/2012	2500							
2/02/2012	2200	780	36	510			730	660
9/02/2012	2300	780	76	410	210	270	540	720
14/02/2012	2200							
16/02/2012	2300	740	72	500			390	790
21/02/2012	2100							
23/02/2012	2200	960	<40	410	230	280	550	1200
28/02/2012	2200							
1/03/2012	2100	820	<40	440			470	770
8/03/2012	1700	540	72	420	210	250	610	1200
13/03/2012	2200							
15/03/2012	2100						560	1100
20/03/2012	2400							
22/03/2012	3500	890	75	1300	200	250	660	1100
27/03/2012	2500							
29/03/2012	2800						900	1200
3/04/2012	2900	1000	82	870	260	300	720	910
19/04/2012	2300	780	44	550	300	360	770	1100
24/04/2012	2600							
26/04/2012	3200						720	1000
1/05/2012	3000							
3/05/2012	2700	840	64	730	290	330	640	980
8/05/2012	2200							
10/05/2012	1900						480	960
15/05/2012	2100							
17/05/2012	2000	570	56	560	250	300	410	1100
22/05/2012	1700							
24/05/2012	1900						400	1400
29/05/2012	1200							
31/05/2012	1500	330	62	530	200	240	220	1300
5/06/2012	1100	200	<40	420	190	230		
12/06/2012	1100							
14/06/2012	960	200	<40	300	180	220	230	1200
19/06/2012	1200							
21/06/2012	1400						230	1200
26/06/2012	840							
28/06/2012	1100	200	<40	320	190	220	130	1100
3/07/2012	950							
5/07/2012	1000	230	<40	260	190	230	150	1200

Table 17: Biogas Methane Concentration – read manually from daily charts

Date	Min	Max	Comment
7/02/2012	62	65	
8/02/2012	62	64	
9/02/2012	62	64	
10/02/2012	62	63	
11/02/2012	61	71	
12/02/2012	70	76	
13/02/2012	69	72	
14/02/2012	63	65	
15/02/2012			No Meter
16/02/2012	62	63	
17/02/2012	63	63	
18/02/2012	64	66	
19/02/2012	67	69	
20/02/2012	65	67	
21/02/2012	65	66	
22/02/2012	65	67	
23/02/2012	65	66	
24/02/2012	64	65	
25/02/2012			No Meter
26/02/2012			No Meter
27/02/2012	66	67	
28/02/2012	65	68	
29/02/2012	60	68	
1/03/2012	64	67	
2/03/2012	63	67	
3/03/2012	62	67	
4/03/2012			
5/03/2012			No Meter
6/03/2012	66	70	
7/03/2012	70	71	
8/03/2012			No Meter
9/03/2012	64	65	
10/03/2012	63	68	
11/03/2012	68	70	
12/03/2012	70	71	
13/03/2012	54	71	
14/03/2012	51	67	
15/03/2012	42	60	
16/03/2012	44	66	
17/03/2012			No Flow

Date	Min	Max	Comment
18/03/2012	19	61	
19/03/2012	21	67	
20/03/2012	25	60	
21/03/2012			No Meter
22/03/2012			No Meter
23/03/2012			No Meter
24/03/2012			No Flow
25/03/2012			No Flow
26/03/2012			No Flow
27/03/2012			No Meter
28/03/2012	63	66	
29/03/2012	26	67	
30/03/2012	64	66	
31/03/2012	66	68	
1/04/2012			No Flow
2/04/2012	67	68	
3/04/2012	63	68	
4/04/2012	60	68	
5/04/2012	67	70	
6/04/2012	67	70	
7/04/2012			No Flow
8/04/2012			No Flow
9/04/2012			No Flow
10/04/2012	74	75	
11/04/2012	75	78	
12/04/2012	60	77	
13/04/2012	70	78	
14/04/2012	72	76	
15/04/2012	74	78	
16/04/2012	67	77	
17/04/2012	62	74	
18/04/2012	65	67	
19/04/2012	61	70	
20/04/2012	64	71	
21/04/2012	67	71	
22/04/2012	68	70	
23/04/2012	50	68	
24/04/2012	54	69	
25/04/2012	69	74	
26/04/2012	64	74	
27/04/2012	59	71	

Table 18: Biogas Methane Concentration – calculated from SCADA data

Date	10%ile	90%ile	50%ile
28/04/2012	68	70	69
29/04/2012			
30/04/2012	70	74	72
1/05/2012	64	70	69
2/05/2012	63	73	70
3/05/2012	65	72	70
4/05/2012	61	69	66
5/05/2012	71	74	73
6/05/2012	73	75	74
7/05/2012	63	74	73
8/05/2012	61	71	68
9/05/2012	65	72	70
10/05/2012	66	73	69
11/05/2012	65	71	70
12/05/2012	66	72	72
13/05/2012	69	74	74
14/05/2012	71	74	74
15/05/2012	69	75	74
16/05/2012	71	74	72
17/05/2012	71	74	72
18/05/2012	68	72	70
19/05/2012	71	73	72
20/05/2012	72	73	72
21/05/2012	64	72	70
22/05/2012	67	72	68
23/05/2012	66	70	69
24/05/2012	68	74	71
25/05/2012	64	72	70
26/05/2012	72	74	73
27/05/2012	73	75	74
28/05/2012	68	75	74
29/05/2012	66	75	71
30/05/2012	68	76	73
31/05/2012	66	75	72
1/06/2012	67	74	71
2/06/2012	73	74	73
3/06/2012	66	73	70
4/06/2012	62	72	68
5/06/2012	66	74	72
6/06/2012	67	75	71
7/06/2012	66	75	71
8/06/2012	70	74	74
9/06/2012			
10/06/2012			
11/06/2012			
12/06/2012			
13/06/2012			
14/06/2012			
15/06/2012			
16/06/2012	67	69	67
17/06/2012	69	72	70
18/06/2012	65	71	66
19/06/2012	67	69	67
20/06/2012	62	70	66
21/06/2012	64	70	65.5
22/06/2012	66	70	68
23/06/2012	67	70	69
24/06/2012	71	72	71
25/06/2012	64	71	70
26/06/2012	70	74	71
27/06/2012	68	70	68
28/06/2012	64	69	66
29/06/2012	61	69	65
30/06/2012	66	68	66
1/07/2012			
2/07/2012	62	69	67
3/07/2012	66	71	67
4/07/2012	66	71	69
5/07/2012	69	72	70
6/07/2012	66	72	70
7/07/2012	70	72	71
8/07/2012	70	72	71

Table 19: Biogas Flow

Date	Raw Flowrate (kL/d)	Smoothed Flowrate (kL/d)
8/02/2012	552	552
9/02/2012		
10/02/2012	237	237
11/02/2012	213	213
12/02/2012	174	174
13/02/2012	94	94
14/02/2012	192	192
15/02/2012	0	
16/02/2012	260	130
17/02/2012	158	158
18/02/2012	341	341
19/02/2012	314	314
20/02/2012	207	207
21/02/2012	105	105
22/02/2012	274	274
23/02/2012	402	402
24/02/2012	160	160
25/02/2012	0	
26/02/2012	0	
27/02/2012	463	
28/02/2012	725	297
29/02/2012	1024	1024
1/03/2012	901	901
2/03/2012	730	730
3/03/2012	364	364
4/03/2012	0	
5/03/2012	758	379
6/03/2012	553	553
7/03/2012	277	277
8/03/2012	237	237
9/03/2012	585	585
10/03/2012	383	383
11/03/2012	390	390
12/03/2012	391	391
13/03/2012	388	388
14/03/2012	459	459
15/03/2012	463	463
16/03/2012	291	291
17/03/2012	0	
18/03/2012	384	
19/03/2012	532	
20/03/2012	1053	492
21/03/2012	603	603
22/03/2012	627	627
23/03/2012		
24/03/2012		
25/03/2012		
26/03/2012		
27/03/2012		
28/03/2012	346	346
29/03/2012	491	491
30/03/2012	733	733
31/03/2012	621	621
1/04/2012	0	
2/04/2012	583	
3/04/2012	904	496
4/04/2012	627	627
5/04/2012	510	510
6/04/2012	391	391
7/04/2012	0	
8/04/2012	0	
9/04/2012	0	
10/04/2012	828	
11/04/2012	980	362
12/04/2012	413	413
13/04/2012	300	300
14/04/2012	271	271
15/04/2012	201	201
16/04/2012	279	279
17/04/2012	303	303
18/04/2012	461	461
19/04/2012	517	517
20/04/2012	404	404
21/04/2012	494	494
22/04/2012	295	295
23/04/2012	595	595

Table 19: Biogas Flow continued

Date	Raw Flowrate (kL/d)	Smoothed Flowrate (kL/d)
24/04/2012	518	518
25/04/2012	327	327
26/04/2012	372	372
27/04/2012	466	466
28/04/2012	77	
29/04/2012	0	
30/04/2012	796	
1/05/2012	973	461
2/05/2012	481	481
3/05/2012	547	547
4/05/2012	541	541
5/05/2012	531	531
6/05/2012	524	524
7/05/2012	550	550
8/05/2012	614	614
9/05/2012	662	662
10/05/2012	672	672
11/05/2012	756	756
12/05/2012	504	504
13/05/2012	656	656
14/05/2012	872	872
15/05/2012	670	670
16/05/2012	741	741
17/05/2012	787	787
18/05/2012	877	877
19/05/2012	804	804
20/05/2012	793	793
21/05/2012	710	710
22/05/2012	833	833
23/05/2012	1017	1017
24/05/2012	787	787
25/05/2012	1004	1004
26/05/2012	814	814
27/05/2012	765	765
28/05/2012	656	656
29/05/2012	736	736
30/05/2012	759	759
31/05/2012	826	826
1/06/2012	818	818
2/06/2012	859	859
3/06/2012	674	674
4/06/2012	285	
5/06/2012	504	504
6/06/2012	641	641
7/06/2012	687	687
8/06/2012	227	
9/06/2012	143	
10/06/2012	84	
11/06/2012	25	
12/06/2012	67	
13/06/2012	30	
14/06/2012	59	
15/06/2012	565	
16/06/2012	1196	
17/06/2012	692	692
18/06/2012	745	745
19/06/2012	107	
20/06/2012	863	863
21/06/2012	760	760
22/06/2012	583	583
23/06/2012	903	903
24/06/2012	544	544
25/06/2012	756	756
26/06/2012	312	
27/06/2012	785	
28/06/2012	1126	
29/06/2012	904	782
30/06/2012	677	677
1/07/2012		
2/07/2012	739	739
3/07/2012	670	670
4/07/2012	804	804
5/07/2012	722	722
6/07/2012	1123	1123
7/07/2012	959	959
8/07/2012	757	757

Table 20: Analysis of individual samples collected over 5th June 2012 production day

Time		7:00	9:00	11:00	13:00	15:00	17:00
BOD	mg/L	1200	810	1900	720	1200	1200
TSS	mg/L	1900	580	3600	1500	1200	1300
pH		7.9	7.9	7.3	8.7	8.0	8.6
COD	mg/L	4100	2200	7900	3300	3000	3900
NH3	mg/L	60	28	29	67	24	28
TKN	mg/L	200	150	290	200	140	360
O&G	mg/L	190	80	240	68	260	<40
pH		8.08	8.12	7	8	8.31	8.57
Temp		23.9	35.9	30	36	36.6	30.9
Cond	mS/cm	23.0	5.37	2.91	4.94	3.09	2.26

Table 21: Field Analysis 1 hourly sampling of 5th June 2012

Time	ID	Cum Flow (L)			pH	Cond. (mS/cm)	Temp (°C)	Comments
7:05	C1	26500265			8.08	23	23.9	green with sediment, salt shed being washed out
8:05	C2	26519830	20	20	8.02	9.48	31.9	green with sediment
9:05	C3	26533330	14	14	8.12	5.37	35.9	dark brown
10:15	C4	26571200	38	32	8.43	3.41	34.7	dark brown
10:55	C5	26606300	35	53	7.37	2.91	29.7	green
11:55	C6	26638500	32	32	8.25	5.73	13	dark brown
13:10	C7	26663525	25	20	8.49	4.94	36	dark brown and smelly
14:35	C8	26708590	45	32	8.28	3.09	35	dark brown
15:00	C9	26716350	8	19	8.31	3.09	36.6	dark brown
16:00	C10	26725494	9	9	8.59	2.95	32.5	reddish brown
17:00	C11	26735450	10	10	8.57	2.26	30.9	reddish

Table 22: GCMS Laboratory Analysis of Biogas sampled on the 6th June 2012

Test Item	unit	Sample 1 at 8am	Sample 2 at 11:55am
CH_4	%	59.5	45.6
CO_2	%	29.1	23.6
O_2	%	2.43	6.59
NH_3	ppm	<0.1	0.1
NO & NO_2	ppm	<0.5	0.5
N_2O	ppm	<5	5
VPH	ppm v/v	<1	1
BTEX	ppm	20	16
CO	ppm	<1	1
H_2S	ppm	2749	254
SO_2	ppm	1	1
Total VFA	ppm	0.025	0.016
Balance (N_2 and Ar)	%	9.0	24.3

Table 23: CAL Crust analysis from 5 June samples

		Screen port	Flare port
TS	%w/w RB	13	10.9
Fixed TS	%w/w DB	14.9	17.6
Org. TS	%w/w DB	85.1	82.4
TKN	mg/kg DB	14,000	32,000
NO_2 as N	mg/kg DB	<250	<250
NO_3 as N	mg/kg DB	<5	<5
TN as N	mg/kg DB		
TP as P	mg/kg DB	2,500	4,400
O&G	mg/kg DB	24,000	25,000

Table 24: CAL sludge analysis from 5 June samples

		CAL Sludge A	CAL Sludge B	CAL Sludge C	CAL Sludge D
TS	%w/w RB	2.65	2.39	2.38	2.22
Fixed TS	%w/w DB	30.4	29.8	30.8	30.8
Org. TS	%w/w DB	69.6	70.2	69.2	69.2
TKN	mg/kg DB	49,000	45,000	55,000	52,000
NO_2 as N	mg/kg DB	<250	<250	<250	<250
NO_3 as N	mg/kg DB	<5	<5	<5	<5
TN as N	mg/kg DB	49,000	45,000		
TP as P	mg/kg DB	7,600	7,000	7,300	8,300
O&G	mg/kg DB				
TDS	mg/L	4,400	4,500	4,400	4,400