ENHANCING BIOGAS PRODUCTION ON AN ANAEROBIC COGENERATION PLANT

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41st Annual WIOA
Queensland Water Industry Operations Conference and Exhibition
Central Queensland University Sports Centre,
Rockhampton
1 & 2 June, 2016

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ABSTRACT

Biogas production from wastewater streams is one of the answers to the energy and environmental needs of the future. Many water authorities are either operating Anaerobic cogeneration plants or have the potential to convert their anaerobic plant to a cogeneration facility. Treating wastewater streams though an anaerobic process to produce biogas energy and treated wastewater simultaneously can provide a significant economic boost for water authorities. Two of the key parameters in maximising the economics of biogas generation from anaerobic systems are the management of H2S formation in the gas and the consistency of the gas generations. Addition of an alkali is typically a critical part of the Anaerobic system for maintenance of pH and alkalinity. Many water authorities do not take advantage of the energy potential their anaerobic systems offer via biogas capture and conversion. Australia only produced 1% of its electricity in 2014 from bioenergy (Clean Energy Australia Report)

A case study was done on a piggery in Victoria that had been producing electricity since 1991 and it was looking to improve biogas/electricity production from the piggery wastewater stream though it anaerobic reactor. This case study started with doing simple lab testing to determine the correct dosing rate for the field trial. In a static the lab trial hydrated lime, caustic soda, standard magnesium hydroxide and ACTI-Mag were tested as potential Alkalis. The ACTI-Mag showed a 3 fold increase in biogas volume generated compared to the other alkaline materials. From this lab testing it was found that between 100-200kg/ML was the optimum dosing rate for this operation. In the field trial 125kg was used on the raw wastewater with the following improvements. 1. Biogas volume increased by 20% 2. Power generation increased by 23.5%. 3. The soluble phosphate reduced by 37.5% in the final waste stream. 4. The H2S level reduced from 800-600 ppm range to below the 200 ppm level. 5. Struvite formation in the pipes and the bell was not seen during the trial having previously formed on regular bases.

1.0 INTRODUCTION

The piggery was located in Victoria and is owned and operated by the family company since 1970. In 1991 it invested 2 million dollars on an anaerobic cogeneration plant and started producing electricity from the piggery effluent. At present the piggery produces 3000kwh per day of electricity. As the price of electricity has risen and the business has grown a desire to improve production of electricity from the anaerobic cogeneration plant developed. The anaerobic cogeneration/wastewater plant has 7 process steps (Figure 1).

- Continuous wastewater collection
- Grit removal
- Concentrating wastewater stream
- Anaerobic acidification (primary digester)
- Anaerobic methanogenic (secondary digester)
- Biogas purification
- Power generation

In this system the heat from the generation is used to heat the primary anaerobic system and preheat the effluent wastewater heading into the anaerobic system.

This Anaerobic system was chosen for this paper as it is a small commercially operated system and the biogas production is used on site for application such as boilers and power generation. Any excess is put on to the electricity grid. It was also chosen because piggeries generally have high levels of H2S and phosphate which can both cause major problems in the generation of power from anaerobic systems. This site was also seen to be operating at it is optimum point.

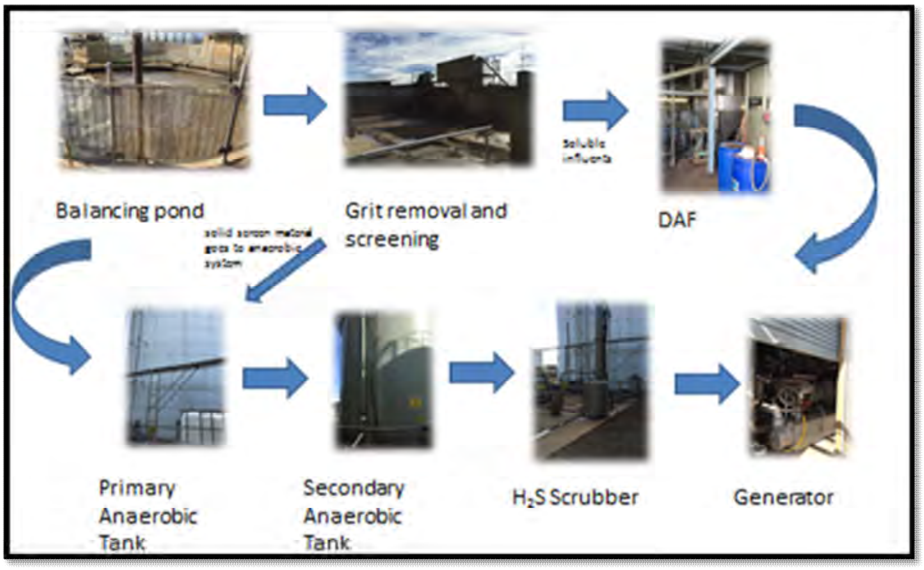


Figure 1: ***Process Diagram.***

Magnesium hydroxide Slurry has been used on many commercial anaerobic systems over the years due it being safe to handle, providing good control of pH, aids removal of phosphate from the effluence and is an effective source of alkalinity. Prior to the trial the anaerobic system did not use any pH adjustment. The effluent coming into the system has of pH 6.8 to 7.2 with an alkalinity of 2800 mg/l. Previous advice from an independent consultant indicated that pH and alkalinity in the effluent were suitable for anaerobic digestion. The addition of 125kg per ML of ACTI-Mag was expected to raise the pH by around 0.2 and the alkalinity by 50 mg/L

Calix limited ACTI-Mag is different from other magnesium hydroxide slurry due to the very high surface area of the Magnesium Oxide from which it is produced. This creates a product that has a significantly higher reactivity than other magnesium hydroxide slurries. The high surface area is the result of the patented Calix process for production of Magnesium Oxide from Magnesium carbonate ore. Unlike other processing plants who take hours to convert magnesium carbonate to magnesium oxide calix do it in seconds using indirect heating.

2.0 DISCUSSION

The first step in this field trial was to conduct a simple lab test on different alkali at different strengths.

2.1 LAB TRIAL

The lab trial was conducted on four alkaline products hydrated lime, 25% caustic soda, standard magnesium hydroxide slurry and ACTI-Mag Magnesium hydroxide slurry.

Each was added to provide equivalent hydroxide levels to the effluent after accounting for the different strengths of each product, (see Table 1). A control into which no chemical was added was tested in parallel.

The test procedure involves taking 500 ml of the anaerobic tank material and adding it to 500 ml of the input influent. The alkaline is then added to the 1 litre bottle at the appropriate rate for each product. A balloon was sealed to the top of the bottle to measure the biogas production. The 500ml of input effluent was made up of 35% from the DAF and 65% from the solids screen flow. Solids content of the final effluent was around the 3.8% ± 0.5

<u>Table 1:</u> ***Dosing Rates and Lab Results.***

Control	Hydrated Lime powder		25% Caustic Soda		Standard MHL		ACTI-Mag	
	Kg/ML	Average Biogas Volume After 6 days (cc)	Kg/ML	Average Biogas Volume After 6 days (cc)	Kg/ML	Average Biogas Volume after 6 days (cc)	Kg/ML	Average Biogas Volume after 6 days (cc)
370 ± 60	76	400 ± 60	324	180 ± 90	100	450 ± 60	100	1165 ± 60
400 ± 80	1114	450 ± 60	486	210 ± 60	150	405 ± 60	150	1110 ± 80
390 ± 50	152	370 ± 60	648	150 ± 30	200	440 ± 60	200	920 ± 70
370 ± 60	228	170 ± 60	972	110 ± 60	300	330 ± 60	300	370 ± 60

From the above result it was show that the ACTI-Mag gave the best results at a dose rate of between 100kg to 200kg was the optimum range.

From these results the caustic soda didn't improve the performance in the lab trial at any concentration and in many cases performed worse than the control. A possible reason for this maybe that caustic soda was causing hot spot and killing off the activated slug. The hydrated lime and standard Magnesium hydroxide slurry did not improve the biogas production much above the control (no chemical added).

2.2 FIELD TRIAL

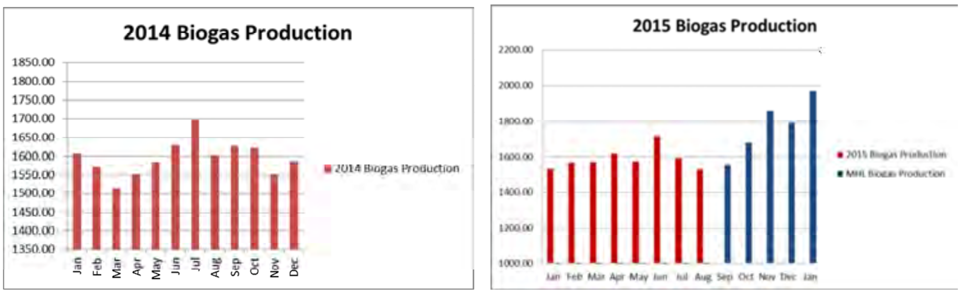
The first part of the field trial was to get historical data (Graph 1 2014). One of the interesting things in the historical data is the rise in biogas production in the winter period and the lower production in the summer period.

This can be explained by the fact that the pigs in the winter period consume more food to stay warm in the winter and less in the summer.

2.2.1 Energy Production

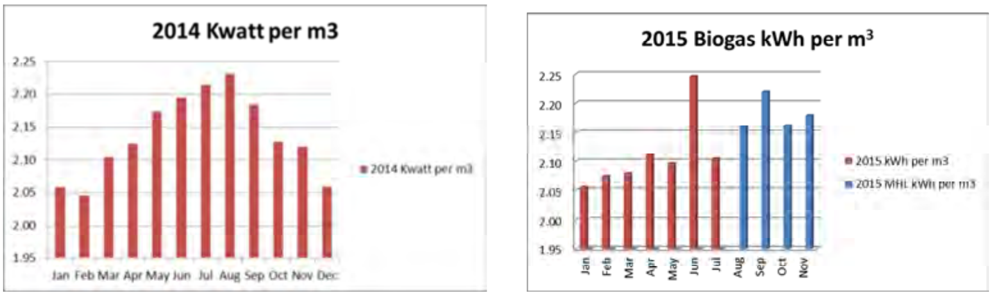
The ACTI-Mag trial started on the 24th August 2015 and within a small amount of time the biogas production started rising (Graph 1) and the biogas quality, as evidenced by the energy generated per cubic metre of gas, also started rise (Graph 2). When looking a historical data the month of November 2014 and 2015 the biogas production average per day were 1550 m^3 and 1860 m^3 respectively. With the use of ACTI-Mag the biogas production increased by 20% from one year to the next.

Graph 1: ***2015 Biogas Production per m^3 per day.***



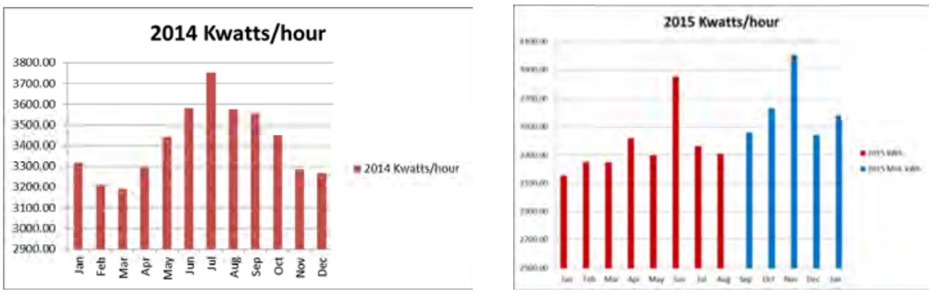
The ACTI-Mag was started being dosing on the 24th August (in Blue).

Graph 2: ***2014 and 2015 kWh per m^3 of biogas.***



Looking at November 2014 to 2015 the kwh per m^3 production increased from 2.12 to 2.18 respectively. Looking at November 2014 and 2015 the power generation per day increased from 3286 to 4061 kwh which is a 23.5% increase in overall power generation per day.

Graph 3: ***Kwh Production per day.***



One of the reasons for the increasing in the biogas production is that the ACTI-Mag chemical promotes hydrolysis or the breaking down of complex carbon molecules into smaller carbon compounds. One of the rate limiting steps in any anaerobic system is the hydrolysis process.

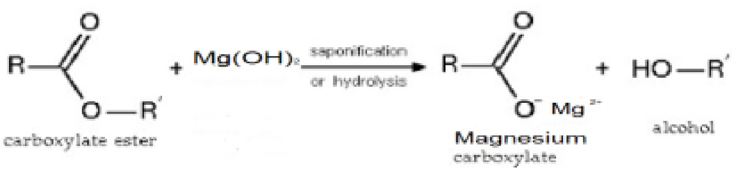
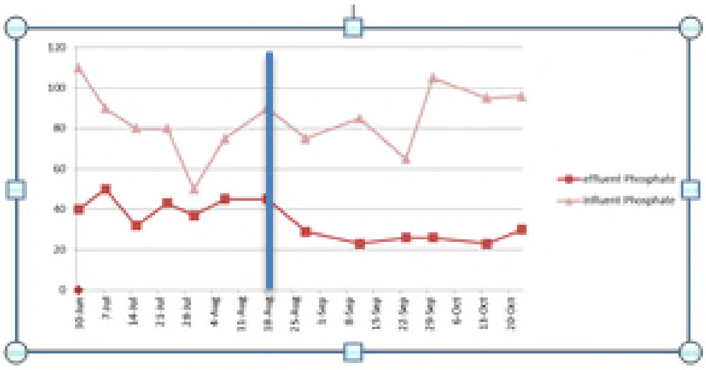


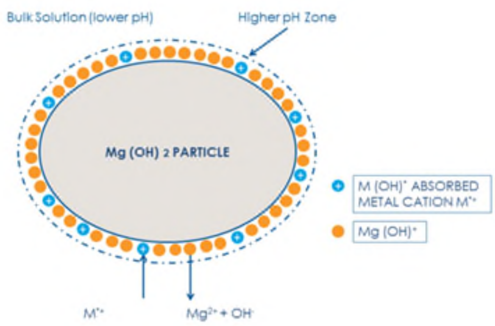
Figure 2: ***Hydrolysis Reaction.***

2.2.2 Phosphate Management

The soluble phosphate level of the incoming and outgoing streams of the anaerobic system was analysed (Graph 4). After the application of the ACTI-Mag the phosphate level in the outgoing stream from the anaerobic system reduced from 40 ± 10mg/L to 25 ±5 mg/L whilst the incoming stream level remained unchanged. This indicated that the ACTI-Mag is forming phosphate precipitation.

<u>Graph 4:</u> ***Soluble Phosphate in the Influent and Effluent.***





<u>Figure 3:</u> ***ACTI-Mag Particle with High Localised pH.***

This system had seen regular blockage in pipes blamed to the formation of struvite. Once the pipes were cleaned and ACTI-Mag dosing begun this problem did not occur during the trial period of 4 months and subsequently has not appeared to April 2016.Thus the use of ACTI-Mag in the system appears to have eliminated the precipitation of Struvite in pipes at the same time as reducing the soluble phosphate level. The mechanism postulated for this is the high surface area and high localised pH on the surfaces of ACTI-Mag particles allows struvite to form on the ACTI-Mag particles and remain in the sludge and not nucleate on the pipes in the system (Figure 3). This observation has led to an ongoing research program at both a University and an industrial site.

2.2.3 H_2S Formation

The H_2S levels of the raw biogas were taken before and during the trial (Graph 5). The H_2S readings were taken on monthly bases with a Dragger gas tube. The application of the ACTI-Mag in August saw a large drop in the H_2S level from 800-600ppm range to less than 200ppm.This allowed the operator to remove the caustic soda chemical scrub out of the biogas processing stream ahead of the gas turbine.

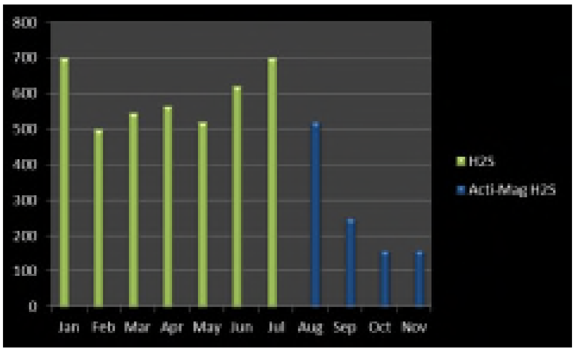
Prior to using ACTI-Mag the process used Ferric Chloride and Polymer in the DAF plant for H_2S management. The ferric chloride was used in the traditional manner with precipitation of the sulphide into ferric sulphide. The addition of the Ferric Chloride into the DAF reduced the pH which is not favourable for the sulphate precipitation reaction. This is counteracted by the addition of ACTI-Mag which stabilised the pH in the DAF thus enhancing the ferrous sulphide reaction.

$$Fe^{2+} + S^{2-} \longrightarrow FeS_{(s)}$$

The Ferric Chloride dose is then much more efficient and the H_2S levels in the gas are lowered. It also helps in the formation of ferric Hydroxide ($Fe(OH)_3(s)$) which will react with the H_2S in the follow reaction.

$$2Fe(OH)_{2(s)} + 3H_2S \longrightarrow Fe_2S_{3(s)}$$

Graph 5: ***H_2S Reading.***



The addition of ACTI-Mag to this wastewater system has also had a financial benefit. Revenue from gas electricity production has been increased and the use of other chemicals has been reduced which easily off-set the cost of the ACTI-Mag addition. The net benefit is approximately $AU 24,363.75 per year.

3.0 CONCLUSION

From this case study the application of 125kg of ACTI-Mag per ML to wastewater has led to the following improvements. 1. Biogas volume increased by 20% 2. Power generation increased has increased by 23.5%. 3. The soluble phosphate has been reduced by 37.5% in the final waste stream. 4. The H_2S level has reduced from 800-600 ppm range to below the 200 ppm level. 5. Struvite formation in the pipes and the bell has been eliminated the piggery has achieved a net financial benefit per year of approximately $24,000.00.

4.0 REFERENCES

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