

DETERMINATION OF SLUDGE ACTIVITY USING AUTOMATED BIOMETHANE POTENTIAL TEST EQUIPMENT



Paper Presented by:

A/Prof Bernadette McCabe

Author:

A/Prof Bernadette McCabe, *Senior Research Fellow,*

National Centre for Engineering in Agriculture,
University of Southern Queensland



*40th Annual WIOA
Queensland Water Industry Operations Conference and Exhibition
Clive Berghofer Recreation Centre,
University of Southern Queensland, Toowoomba
16 to 18 June, 2015*

DETERMINATION OF SLUDGE ACTIVITY USING AUTOMATED BIOMETHANE POTENTIAL TEST EQUIPMENT

A/Prof Bernadette McCabe, *Senior Research Fellow*, NCEA, University Southern Queensland.

ABSTRACT

A number of test procedures have been reported in the literature for determination of the specific methanogenic activity profile of anaerobic sludges. Sludge activity measurements can be performed in two ways: 1. An overall measurement which gives information about the whole degradative activity using substrates such as cellulose, starch or gelatine and 2. An activity measurement of each basic stage of the process; for example, to determine the quality of a sludge sample in terms of methanogenic activity a substrate such as acetate is used to indicate how fast a certain quantity of sludge can convert acetate to methane.

This paper provides an overview of the various methods that exist and presents data obtained in the authors' laboratory for the testing of overall sludge activity using automated biomethane potential test system (AMPTS) using cellulose as the substrate. The case study chosen represents a novel investigation of sludge activity of an anaerobic lagoon treating high strength abattoir waste water.

1.0 INTRODUCTION

One of the most suitable technologies to treat wastewater from red meat processing industry in Australia are anaerobic ponds (also known as lagoons). They are one of the oldest and simplest forms for domestic and industrial waste and are used extensively for agricultural industries such as piggeries, dairies, tanneries and abattoirs. However, they have a couple of issues including odour emissions and the generation of methane, a powerful greenhouse gas. Over the last 15 years these industries have begun installing covered anaerobic pond technology in an effort to confront and solve these two most pressing problems. The addition of a cover reduces heat loss from ponds, reduces odour emissions, and allows the capture of biogas in the form of methane for flaring or energy generation to produce heat, generate electricity, and fuel engines (Johns, 1995).

The successful commissioning of a covered anaerobic lagoon is dependent on a range of factors, including the use of active sludge as seed inoculum. Sludge activity measurements can be performed in two ways:

1. An overall measurement which gives information about the whole degradative activity. In this situation standard substrates such as cellulose, starch or gelatine are used (Soto et al., 1993, Raposo et al, 2011).
2. An activity measurement of each basic stage of the process. To determine the quality of a sludge sample in terms of methanogenic activity a substrate such as acetate is used to indicate how fast a certain quantity of sludge can convert acetate to methane (Sorenson and Ahring, 1993; Bunter et al, 2014).

While an overall activity measurement allows the selection of an adapted sludge to be used as an inoculum in an anaerobic digester, an individual activity determination can be useful for the identification of potential unbalanced situations among the different groups of microorganisms.

An application of this methanogenic testing is to determine the toxic effect that a

specific wastewater exerts on an anaerobic sludge.

NH Foods Australia (NHA) Oakey Beef Exports (OBEX) have recently commissioned a covered high rate anaerobic lagoon (COHRAL) at Oakey Abattoir, on the Darling Downs in Queensland. Prior to commissioning, the plant considered the utilisation of sludge from the existing anaerobic pond to act as seed inoculum for the new covered lagoon. In order to select an appropriate sludge which will ensure optimal biogas during the critical start-up period it is necessary to determine the activity of the sludge. This paper firstly describes a protocol for the testing of overall sludge activity using cellulose as the substrate. It then proceeds to report on the sludge activity of existing anaerobic ponds at the Oakey Abattoir site using various sludge samples sourced from different locations and depths.

2.0 DISCUSSION

2.1 Description of AMPTS Set Up

A multi-channel analyser was used to perform the sludge activity test. The Automatic Methane Potential Test System (AMPTSII, Bioprocess Control, Sweden) consists of fifteen parallel reactors and the same number of gas flow meters attached to a data acquisition system (Figure 1).

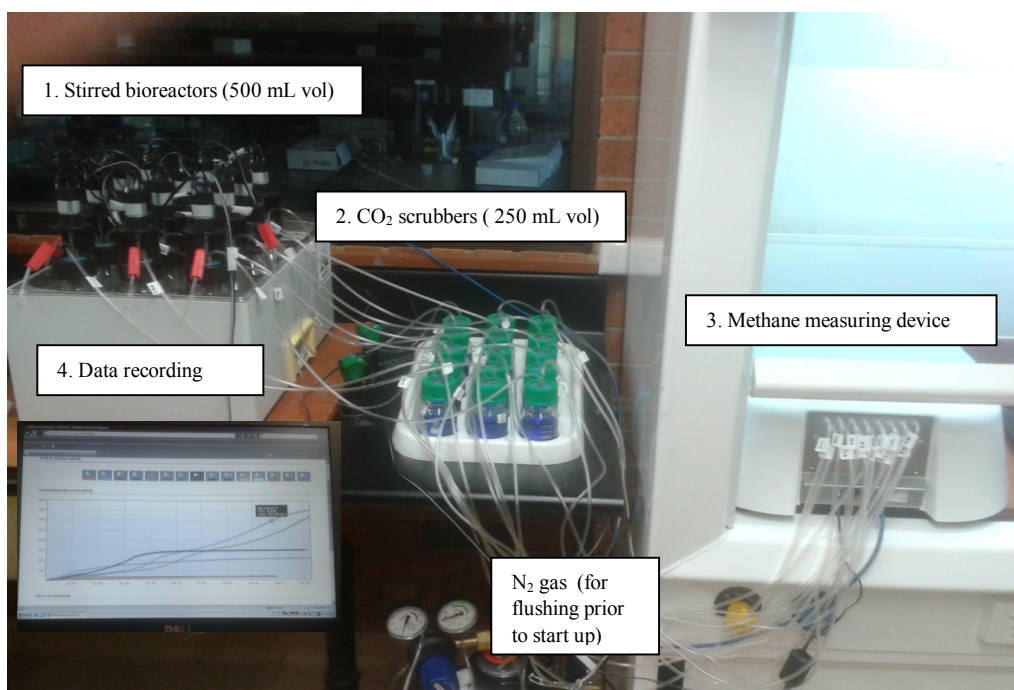


Figure 1: *Laboratory Set Up of the Automatic Methane Potential Test System*

A schematic representation is shown in Figure 2. Biogas, mixture of methane and carbon dioxide, produced in temperature controlled reactors (fifteen sets) each with an overhead stirrer (1) pass through one-way valves and enter into scrubbing solution (3M NaOH) units (fifteen sets) where carbon dioxide is fixed (2) and methane passes to the sensor chamber (fifteen sets) (3) where the volume is quantified and recorded by the software (4). Arrow shows the direction of gas flow.

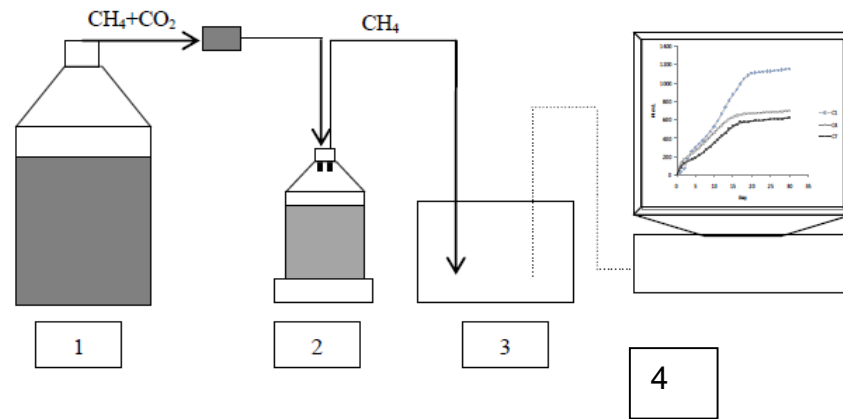


Figure 2: *Schematic Presentation of AMPTS*

2.2 Sludge Source

Two sludge sources from Oakey Beef Exports were identified as possible candidates to act as seed inoculum: a) sludge sourced from the anaerobic pond and b) sludge sourced from the serpentine pond (a facultative pond) which directly receives effluent from the anaerobic pond. Figures 3a and b are photographs of the anaerobic pond and the serpentine respectively.

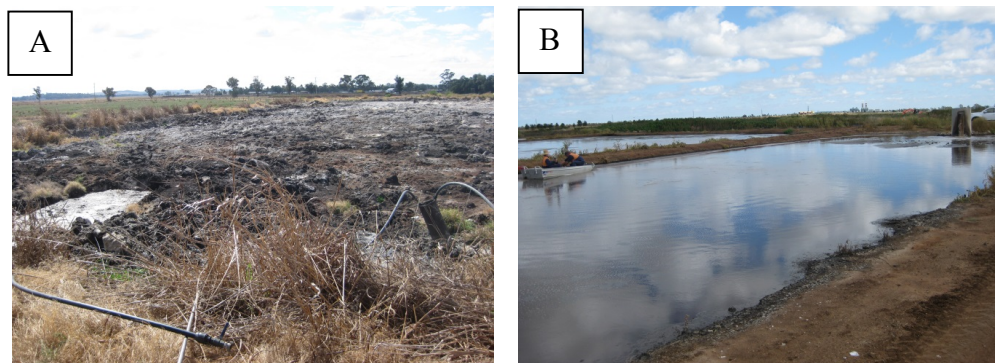


Figure 3: *Photographs of both the Anaerobic Lagoon (A) and Serpentine (B)*

A sampling protocol is presented in Table 1 below which takes into account sludge from different locations and depths from these two sources. Dimension of anaerobic pond is 50m (l) x 35m (w) x 8m (d). Depth for serpentine pond below represents the base of the channel where the samples were taken.

Table 1: *Sludge Sources and Depths*

Anaerobic Pond	Depth (m)	Serpentine pond	Depth (m)
L1D1 and L1D2	0.5-0.7 and 1.0-1.12	L6	0.6
L2D1 and L2D2	1.5-1.7 and 2.5-2.7	L7	0.7
L3D1 and L3D2	2.0-2.2 and 2.5-2.7	L8	0.8
L4D1 and L4D2	2.0-2.2 and 2.8-3.0	L9	0.8
L5D1 and L5D2	2.5-2.7 and 2.8-3.0	L10	0.8
		L11	0.7
		L12	0.9

2.3 Test Substrate

Cellulose powder (Fluka, Avicel PH-101, ~50 µm particle size) was used as a test substrate to give information about the whole degradative activity of the sludge samples. The following details were measured for cellulose:

Total Solids (TS): 95.5%
Volatile Solids (VS) (%TS): 99.999%
VS (total): 95.534%
Moisture Content (MC): 4.24%

2.3 Sludge (inoculum) Preparation and Analyses

After collection the various seed sludge samples were screened until the particles were a maximum of 8 mm. The TS, VS, total volume and sludge volume (SV30) of every sludge sample before and after the screening was measured to determine the screening efficiency. The pH, chemical oxygen demand (COD) (total and soluble) and a volatile fatty acid (VFA) profile (via GC analysis) of every sludge sample was taken after the screening step prior to and after sludge activity testing.

2.4 Preparation of Bioreactors and Start Up Procedure

A total amount of 400 g liquid per bioreactor (for 500 mL bottle) was used. This included 300 ml inoculum (sludge) and the solid substrate (cellulose) mixed in 100 ml distilled water. For each sludge sample a corresponding blank control containing only sludge was used. This was used to compensate for the amount of methane produced by the inocula itself. An Inoculum Substrate Ratio (ISR) of 2:1 was used and calculated as follows:

$$\text{ISR } 2:1 = (M_{\text{inoculum}} \times \text{VS}\%_{\text{inoculum}}) / (M_{\text{substrate}} \times \text{VS}\%_{\text{substrate}})$$
$$M_{\text{total}} = M_{\text{inoculum}} + M_{\text{substrate}} = 400 \text{ g}$$

Where M = amount in grams

2.4 Results

The continuous nature of data acquisition in AMPTS allows for high data accuracy and precision and is useful in extracting important kinetic information of the degradative process. The biomethane potential of the cellulose is plotted as L CH₄ /kg VS sludge loaded (corrected for standard conditions). The average methane yield for cellulose at an ISR of 2:1 is approximately 350 L methane/kg VS.

Figures 4 and 5 shows the results of biomethane potential of the cellulose when incubated with sludge from the anaerobic pond and the serpentine pond respectively. For the anaerobic pond, three out of ten sludge samples returned a reasonable biomethane activity close to the average yield of 350 L methane/kg VS cellulose (Figure 4). These sludge samples were located fairly close to the outlet point (location 2 and 4). It is known that anaerobic ponds tend to develop 'dead spots' of activity over the life of the pond and sludge tends to build up at the inlet. In comparison, biomethane potential of cellulose samples using all 7 sludge samples sourced from the serpentine pond gave results which were close to the average yield of 350 L methane/kg VS cellulose (Figure 5).

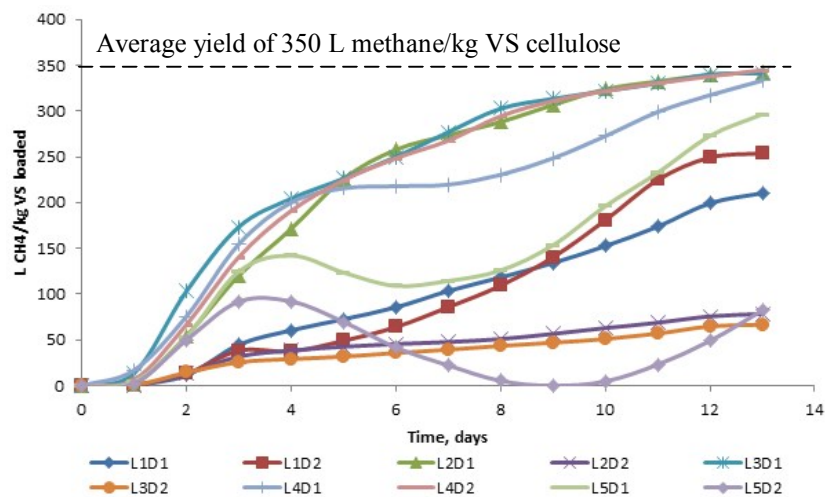


Figure 4: Comparative Biomethane Potential (BMP) of Anaerobic Pond Sludge

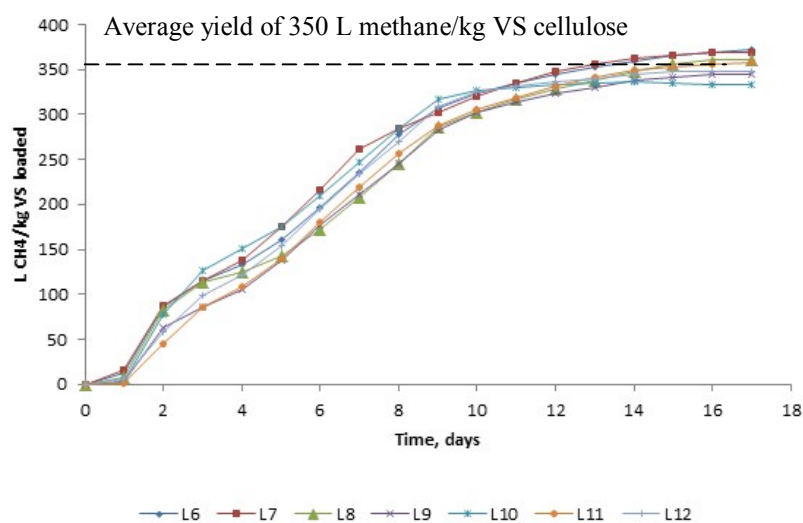


Figure 5: Comparative Biomethane Potential (BMP) of Serpentine Sludge

Table 2: Summary of Methane Production and Sludge Activity

Anaerobic pond			Serpentine pond		
Sample	Methane production (mL CH ₄ /g VS removed)	Sludge activity, %	Sample	Methane production (mL CH ₄ /g VS removed)	Sludge activity, %
L1D1	241.68	57.54	L6	372.28	88.63
L1D2	264.87	63.06	L7	368.61	87.76
L2D1	303.49	72.25	L8	361.32	86.02
L2D2	209.52	49.88	L9	345.21	82.19
L3D1	243.21	57.90	L10	333.67	79.44
L3D2	No result	No result	L11	358.19	85.28
L4D1	316.32	75.31	L12	348.58	82.99
L4D2	323.80	77.09			
L5D1	229.61	54.67			
L5D2	75.89	18.07			

Table 2 shows the methane produced ie biomethane potential (BMP) as mL CH₄/g VS removed and corresponding sludge activity. Sludge activity was calculated using the BMP by taking into account that 1 kg COD removed corresponds to 350 L CH₄ produced. The highlighted results in Table 2 show the location and depth where sludge from the anaerobic pond showed reasonable comparison with the average yield of methane from cellulose. The sludge from all location and depths from the serpentine pond showed good comparison and gave a sludge activity ranging from 79% to 89%.

3.0 CONCLUSION

The results of this study show that the location and depth of sludge obtained from the anaerobic pond differs and that given the age of the pond (~15 years) the activity of sludge at the outlet at depths of 1.5 to 3m provide reasonable activity of 75%. The serpentine (facultative) pond provided more suitable results and therefore represents a better candidate in terms of seed inoculum for the new covered high rate lagoon.

This paper has provided an insight into sludge activity using an automated biomethane potential testing equipment and the application of this in determining sludge activity treating high strength abattoir wastewater. There is very limited knowledge on the activity of sludge and the accumulation thereof over the life span of anaerobic ponds treating waste water in the red meat processing industry. This is of increasing importance given the move toward using covered anerobic ponds for the capture of methane for energy generation to produce heat, generate electricity, and fuel engines.

4.0 ACKNOWLEDGEMENTS

This project was commissioned by NH Foods Australia, Oakey Beef Exports, Oakey, Queensland. Support provided by staff at OBEX and the technical assistance and data analysis provided by Ihsan Hamawand (NCEA) is gratefully acknowledged.

5.0 REFERENCES

- Butner D Spanjers H and van Lier J B. (2014). *The influence of hydrolysis induced biopolymers from recycled aerobic sludge on specific methanogenic activity and sludge filterability in an anaerobic membrane bioreactor*. Wat. Res. 51: 284-292.
- Johns M. (1995). *Developments in wastewater treatment in the meat processing inudstry: A review*. Bioresour. Techonol. 54: 203-216.
- Raposo F Fernandez-Cegrei V Dela Rubia M A Borja R Beline F Cavinato C Demirer G Fernandez B Fernandez-Polanco M Frigon J C Ganesh R Kaparaju P Koubova J Mendez R Menin G Peene A Schere P Torrijis M Uellendahl H Wierinck I and de Wildep V. (2011). *Biochemical methane potential (BMP) of solid organic substrates: evaluation of anaerobic biodegradability using data from an international interlaboratory study*. J Chem Technol Biotechnol. 86: 1088-1098.
- Sorenesen A H and Ahring B K. (1993). *Measurement of specific methanogenic activity of anaerobic digester biomass*. Appl Microbiol Biotechnol. 40: 427-431.
- Soto M Menedez R. and Lema J M. (1993). *Methanogenic and non-methanogenic activity tests. Theoretical basis and experimental set up*. Wat. Res. 27(8): 1361-1376.