Meat technology update

4/10 – October 2010

Covered anaerobic ponds

Anaerobic ponds are widely used in the meat industry as the first stage of secondary treatment of abattoir wastewater. They are popular because they have a high BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) removal efficiency of around 90%, with a reasonably sized footprint and low operational costs; however, they have a couple of issues:

- **odour emissions; and**
- **the biogas produced contains a high percentage of methane (CH_4) which is a powerful greenhouse gas with a global warming potential (GWP) 21 times that of carbon dioxide (CO_2).**

Therefore, environmental regulatory authorities are generally requiring that anaerobic ponds be covered to contain emissions.

The anaerobic process

Anaerobic digestion is the action of specialised bacteria, including acid-forming acetogens and methane-forming methanogens, in the absence of oxygen. The anaerobic digestion process consists of four biological and chemical stages where complex organic material is broken down into simpler organic compounds, and eventually into CH_4, CO_2 and non-degradable residues (Figure 1).

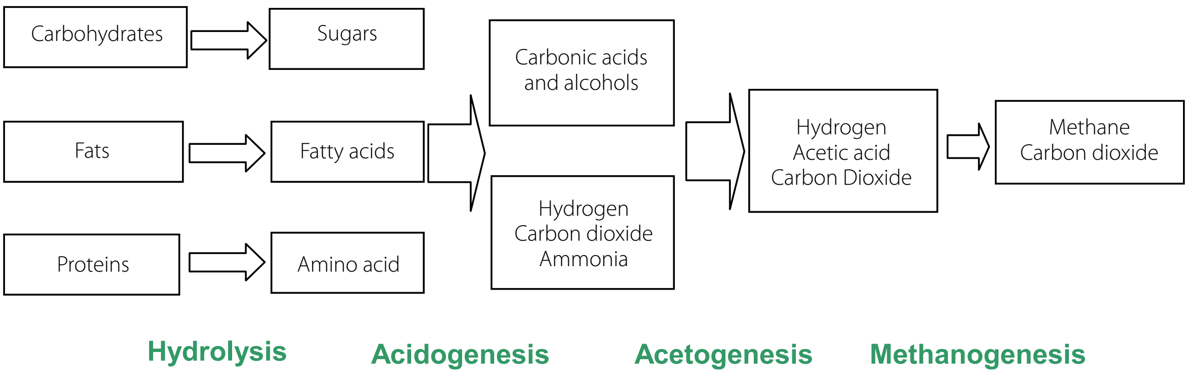

Figure 1: The anaerobic process

A simplified chemical equation for the overall process is:

$C_6H_{12}O_6 \longrightarrow 3CO_2 + 3CH_4$

The anaerobic process is temperature and pH dependent. Some bacteria involved in the process have an optimum temperature range of 30–40°C. They are mesophiles or mesophilic bacteria. Others prefer much hotter conditions of 55–75°C and are called thermophiles or thermophilic bacteria. The rate of reaction is higher in the thermophilic range, but the additional heating required to maintain the required temperatures usually makes thermophilic digestion uneconomical. Sewage sludge digesters are heated to maintain the mesophilic temperatures, but anaerobic lagoons treating wastewater are unheated. As the pond temperature drops during winter the rate of methane production falls—and ceases below about 15°C. In areas where the pond temperature is likely to be low for periods of a month or more, anaerobic ponds may not be an appropriate solution.

Methane-producing bacteria are sensitive to pH and operate over the range pH 6.5 to 8.0 with the optimum near 7.0. If the rate of acid production exceeds the rate of breakdown to methane, the pH decreases, gas production falls and the CO_2 content of the biogas can increase.

Pond design

Anaerobic ponds are normally sized based on an organic loading rate and detention time. The loading rate is based on the biochemical oxygen demand (BOD) of the inflowing waste stream and a large range of rates and detention times are quoted in publications. For meat industry applications, loading rates in the range 0.05–0.08 kg BOD/m^3.day, with detention times of 20 to 40 days, have been used successfully.

In order to maintain anaerobic conditions, ponds should be greater than 3 m deep, but depths of up to 10 m have been used. Ponds are mostly in the range 3 to 6 m deep depending on soil conditions and the level of the water table. Ponds should be lined to prevent seepage into the ground water. The lining may be clay or a suitable polymer material.

Figure 2: Covered anaerobic pond

The inlet to the pond should be near the bottom and the outlet about 300 mm below the water surface and positioned to avoid short-circuiting. A single pond may be used, but two ponds in series or parallel may offer more flexibility when maintenance such as desludging is required.

Recommended design parameters are:	
Loading rate	0.05–0.08 kg BOD/m3.day
Hydraulic detention time	20–40 days
Depth	3–5 m
Length to breadth ratio	3:1
Freeboard	0.5 m min.
Internal slope	2 to 3:1 depending on soil

Methane yield

The composition of the biogas produced from anaerobic digestion depends on the input material, but for wastewater from abattoirs it will be about 65% CH4 with CO2 being the other major constituent with other minor gases. The typical range of constituents in biogas is shown in Table 1 (right).

Based on the degradation of COD, the theoretical yield of methane from an anaerobic pond is 0.35 m3 per kg of COD removed (CODR). In practice the CH4 yield may be lower. Yield from a laboratory-scale anaerobic fluidised-bed reactor, was reported to be 0.32 m3/kg CODR when operating on slaughterhouse wastewater with an input COD of about 5000 mg/L. At the other extreme, trials with a covered anaerobic lagoon at an Australian abattoir in the mid 1990s reported biogas yields of 0.21 m3/kg CODR, which at 65% methane equates to ~0.14 m3 CH4/kg CODR. The average input COD was 6375 mg/L with a removal

Table 1: Composition of biogas (Stafford et al., 1980)

Component	Percentage
Methane	60–70
Carbon dioxide	30–40
Hydrogen	1–2
Hydrogen sulphide	0–0.3
Carbon monoxide	0–1
Nitrogen	0–4
Other gases	Trace

efficiency of 87%. The Australian Meat Industry Council submission to the Federal Government Green Paper on Climate
Change used a biogas production figure from anaerobic ponds of 0.5 m^3/kg COD_R at 60% CH_4 which is equivalent 0.3 m^3 CH_4/kg COD_R.

BOD or COD?

Biochemical oxygen demand (BOD) is a measure of the amount of dissolved oxygen needed by aerobic biological organisms in the water to break down organic material present, at certain temperatures over a specific time period.

Chemical oxygen demand (COD) is a measure of the amount of organic compounds in water.

COD values are usually higher than BOD values, because the chemical oxidant can oxidise some inorganic materials as well as many organic materials. The ratio of COD to BOD depends on the constituents in the sample.

Pond covers

Traditionally, operators of anaerobic ponds have relied on the development of a crust to contain odours, but this is not a reliable method and the crust can take some time to form. A geomembrane cover (figure 2) that is fixed to the pond bank is a much more reliable method and the biogas captured can be either flared off or used as a fuel.

Pond cover material

A range of materials has been used for pond covers both in Australia and overseas, and some have performed better than others. A recent study for MLA compared the properties and performance of a range of materials that can be used to manufacture pond covers. The materials were:

- high density polyethylene (HDPE);
- low linear density polyethylene (LLDPE);
- flexible polypropylene (fPP);
- reinforced ethylene interpolymer alloy (R-EIA);
- chlorosulphonated polyethylene (CSPE).

Some of the properties evaluated were: tear resistance, flexibility, resistance to fats and oils, UV resistance, ease of repair and cost (Table 2).

Meat industry ponds will generally have a surface layer of floating fat that is in contact with the cover, therefore the material should have good resistance to fats, oil and grease (FOG). The material must also be resistant to UV radiation due to the high UV radiation levels in most of Australia.

HDPE would be the most suitable material where the cover is fixed, but it is not as flexible as other materials and may not perform well if there is rise and fall in the water level. CSPE and R-EIA are more flexible and are more suitable for variable elevation ponds, but CSPE cures with time and R-EIA can crack and degrade at the edges if the scrim reinforcement is left exposed. LLDPE and fPP are also flexible and cheaper than R-EIA and CSPE, but are not as resistant to FOG (see Table 2).

HDPE is generally the material of choice for pond covers due to its ready availability, low cost and chemical robustness.

Cover design

The construction of the cover needs to meet several criteria, including:

- secure anchorage to the bank;
- a method of collection of biogas;
- an ability to remove stormwater from the surface;
- consideration of method of removal of scum and sludge.

The pond cover is usually anchored by burying it in a perimeter trench or anchoring to a concrete kerb. The cover can be designed to float on the surface under negative pressure or, in the case of a positive pressure cover, be allowed to inflate as the biogas is generated. The positive pressure cover may need to be made from a more flexible material, but stormwater drainage and gas collection are simpler; however this design may not be suitable in areas of high winds—which have the potential to damage the cover material.

In covers that are fixed to the surface, gas can be collected using a slotted pipe around the perimeter of the cover that is connected to a fan from where it can be combusted in a flare or treated for other uses (Figures 3 and 4).

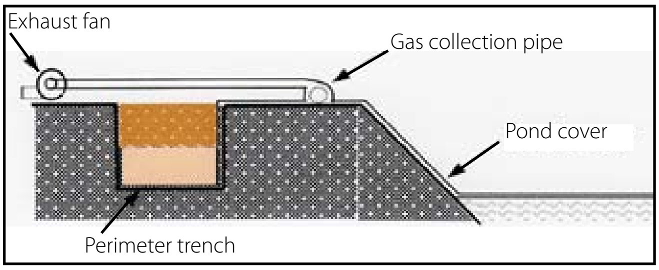

Figure 3: Schematic arrangement of pond cover attachment

Pond covers are usually made of a black material which will absorb heat and help to maintain the pond temperature during winter months. Light-coloured materials are also used and these may have better resistance to UV degradation due to the lower surface temperature.

Figure 4: Anaerobic pond cover in place, with gas collection pipes

Table 2: Comparison of materials (Golder Associates, 2009)

Cover material	HDPE	LLDPE	fPP	R-EIA	CSPE
Material cost	Least expensive	Similar to HDPE	More expensive than LLDPE	More expensive than fPP	Most expensive
Flexibility	Poor flexibility	Good flexibility	Best flexibility	Very good flexibility	Very good flexibility
Resistance to wind uplift	Good wind resistance	Good wind resistance	Poor wind resistance	Moderate wind resistance	Highest wind resistance
UV resistance	Good UV resistance	Moderate UV resistance	Good UV resistance	Good UV resistance	Good UV resistance
FOG resistance & durability	Good FOG resistance	Moderate FOG resistance	Poor FOG resistance	Good FOG resistance	Good FOG resistance
In-service repair	Easy to repair	Easy to repair	Difficult to repair	Moderately easy to repair	Most difficult to repair

A method of removing water from the surface of the cover is required, especially in high rainfall areas. One method is to create channels in the cover by placing weighted pipes on the surface such that the rainfall is directed to a sump from where it can be pumped away (Figure 5).

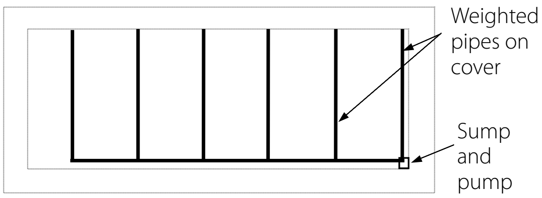

Figure 5: Possible layout of rainwater collection system

Anaerobic ponds, whether covered or not, should be fenced to prevent stock or native animals walking onto them. There have been cases of kangaroos damaging covers with their claws.

Pond crust

Meat plant anaerobic ponds normally develop a surface crust quite rapidly and, over several years of operation, this can become quite solid. If retrofitting a cover to an existing pond, it may be advisable to remove the crust prior to fitting the cover.

If a crust develops under a cover, the 'scumbergs' (as they are sometimes called) could have the following effects:

- give rise to 'whalebacks' or humps in the cover;
- apply shear loads and localised stresses to the cover;
- restrict free movement of the cover during thermal cycles;
- subject the cover to concentrated fatty acids, greases, oils and their degradation products.

The design of the cover and the material used should take into account the possible effects of the floating crust under the cover. If the crust has to be removed, this can be done by flushing out with the stored liquid or by removing the cover to mechanically excavate it. Removal of the cover could damage it—especially if it has lost some flexibility—and allow odours to escape. Excessively thick or rapid formation of crust could indicate problems within the pond. In this case, expert advice should be sought.

Biogas utilisation

The biogas captured from a covered anaerobic pond is rich in methane so, therefore, has a heating value and is also a greenhouse gas (GHG). The options for utilising the gas listed from lowest to highest capital cost are:

- flaring adjacent to the point of collection;
- burning in a gas-fired boiler;
- using to fire an absorption refrigeration plant;
- using to fuel a gas engine or turbine for cogeneration, for example, with a waste heat absorption chiller.

Other options could include compression for use as a transport fuel in vehicles converted to run on compressed natural gas (CNG).

Methane has a net heating value of approximately 35 000 kJ/m^3 and burning it will reduce its GHG potential by over 98%. Before it is used it may have to be treated by scrubbing to remove impurities such as hydrogen sulphide. Biogas from digestion of abattoir effluent may contain high levels of hydrogen sulphide which is corrosive to copper and brass, and is poisonous. Also, the gas is produced at 100% RH and there should be provision for removal of condensate from pipelines.

The economics of utilising the biogas for processes on the plant are dependent on the cost of energy, whether a price is placed on emissions, the capital cost of equipment, distance between the pond and the plant, and whether government assistance is available.

The potential to use absorption refrigeration equipment with cogeneration systems has been investigated, but as a result of very high capital cost, these options are the least viable under current conditions in Australia. Flaring the gas at the point of capture or burning in a gas-fired boiler are lower-cost options. The distance between the pond and the boilerhouse will affect the viability of use as a boiler fuel. If considering using biogas as a fuel, a detailed analysis should be done taking into account current and projected fuel and electricity costs, installation costs and government policy on emissions.

Further reading

Golder Associates Pty Ltd (2009). Anaerobic cover material vulnerability—assessment of available cover materials. Report to Meat & Livestock Australia, Project A.ENV.0072.

New Zealand Pork (2008). Covered anaerobic ponds for anaerobic digestion and biogas capture: piggeries. NIWA Information Series No. 32. http://www.biogas.org.nz/Publications/WhosWho/biogas-pond-booklet.pdf

Stafford, D.A., Hawkes, D.L. & Horton, R. (1980). Methane production from waste organic matter. CRC Press, Inc.

Contact us for additional information

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