Bioenergy Support Program

Talking Topic 4

Cleaning piggery biogas

Cleaning piggery biogas

Biogas is naturally produced when manure is treated in effluent ponds. **Biogas is a good fuel** for heating or electricity generation. Using biogas **reduces energy costs, decreases piggery odour** and **reduces greenhouse gas emissions** (See Talking Topic 3). Using biogas can also provide **income** from the **sale of** excess **electricity** back to the grid and the **sale of credits** (See Case Study 1 and Talking Topic 6).

WHY CLEAN BIOGAS?

Piggery biogas is an excellent fuel with a high methane content (55–70% by volume) but requires some treatment/cleaning before use to ensure it is safe and cost effective.

Biogas is cleaned to remove moisture and hydrogen sulphide. Moisture is removed because it can restrict the flow of biogas to a biogas appliance such as a hotwater system or an internal combustion engine generator. Hydrogen sulphide is also removed before it causes wear-and-tear of equipment and because it is very dangerous (See Talking Topic 2).

Minimising the complexity of a biogas system as much as possible, minimises costs while ensuring safe and consistent performance with minimal human intervention.

In all cases, it is prudent to

- place a high priority on safety;
- prefer gravity flow over pumping where possible;
- prefer biological treatment over chemical treatment, because the former can have lower running costs and requires less intervention;
- prefer passive treatment over active treatment (See page 8) e.g. cooling and condensing moisture in underground pipelines with a natural fall to safely drain condensate, instead of active cooling using an electric chiller unit to condense moisture from biogas;
- prefer transfer of biogas over long distances, instead of transfer of manure
- prefer transfer of biogas over long distances, instead of transfer of electricity produced from biogas; and
- with pumping of biogas, experience to date suggests that the placement of a biogas pump (blower) is important from a regulatory perspective. This is because in some states of Australia the biogas pipelines and treatment vessels are more stringently regulated if under a positive pressure (as when located after a blower) as opposed to being at a slight negative to low pressure (as when located before a blower).

These concepts are interweaved into the biogas cleaning approaches described below.

CASE STUDY 1

Real Piggery 2200 sow Farrow-to-Finish NSW

- All conventional flushed sheds
- Covered anaerobic ponds (CAPs)
- $980,000 investment in 2011–2012 to build biogas system. 2.5-year payback (paid back by July 2015)
- 280 kWe electricity generation with heat recovered for farrowing and weaner shed heating
- $15,000 per month in energy costs saved from using biogas
- In addition, 60% of electricity produced is exported to the grid, earning $5,000 per month income
- 8,500 tonnes CO2-e per annum of greenhouse gas emissions prevented, earning an estimated $160,000 per annum income from sale of carbon credits
- Sale of renewable energy credits (additional to carbon credits) roughly pays for the on-going operation and maintenance costs of the biogas system, including engine generator maintenance
- Raw biogas from the CAP is treated by biological oxidation, followed by chemisorption, before a blower boosts the biogas pressure to 15 kPa
- Subsequent to the blower, a chiller unit cools the biogas to remove moisture before the biogas is conveyed to a separate piggery site through 3.5 km long underground pipelines
- Odour emissions from the covered lagoon and biogas equipment are considered to be minimal

Cleaning piggery biogas

FIGURE Biogas equipment at Case Study 1 piggery

Biogas cleaning approaches

Piggery biogas has to be

1. cleaned of hydrogen sulphide (unless the biogas is burnt in a flare);
2. pumped using a biogas blower (Figure 1); and
3. dried.

The approaches described below specifically target moisture and hydrogen sulphide, but can also remove aerosols and dust to prevent damage to biogas equipment (See Case Study 2). Siloxanes, halogenated and hydrocarbon impurities are other important impurities, but these are usually only found at significant concentrations in biogas that is produced when other wastes are also treated in a covered pond or digester together with the pig manure. Siloxanes, halogenated and hydrocarbon impurities are not specifically addressed here, but by removing hydrogen sulphide (See Case Study 4), the separate treatment for siloxanes may also be improved.

CASE STUDY 2

Impurities and Biogas Flow Metering

A piggery in Victoria Australia was registered in 2014 to earn and sell carbon credits under the Carbon Farming Initiative (Now the Emissions Reduction Fund), and for this purpose the amount of biogas being burnt in an onsite flare was measured using a flow meter. Because the biogas was not being treated before flowing through the flow meter, impurities in the untreated biogas passing through the flow meter caused excessive wear-and-tear of the flow meter components, leading to inaccurate readings. Fortunately, recalibration of the meter indicated that the meter had been underestimating the biogas flow volume, so the producer was able to claim 9,590 carbon credits subsequently sold for an estimated $240k. However, the unreliable flow measurements considerably reduced the number of carbon credits that could be claimed, thereby reducing the income from their sale. To prevent a reoccurrence, the producer installed a different type of self-calibrating **biogas flow meter**, **without** the **moving parts** to be less prone to damage by untreated biogas.

FIGURE 1 Various biogas blowers at Australian piggeries. Blowers boost the pressure of biogas so that it can flow via subsequent pipelines and treatment vessels to the biogas appliance. Often there are condensate collection drums in the pipeline before the blower to protect the blower from entrained moisture droplets.

Drying of biogas

Biogas is often saturated with moisture (i.e. laden with water vapour), so that if the biogas is cooled, moisture will condense to a liquid. This condensate can restrict biogas flow. Biogas treatment often involves cooling the biogas in a controlled manner to capture condensate before it causes problems.

At a higher temperature, biogas contains more moisture (Figure 2). This is important because biogas temperatures can be as high as 65ºC in a sun-baked covered lagoon (Skerman and Collman, 2012), so the biogas in this case can contain a lot of moisture. This moisture can be removed by cooling the biogas with chilled water supplied by an electrical chiller (See Case Studies), which consumes electricity.

Instead, Pork CRC demonstration piggeries are trialling passive pre-cooling by contacting the biogas with a cool liquid water such as effluent from a greywater storage dam and subsequently simply cooling the biogas in underground pipelines with an adequate slope to safely drain condensate into a collection drum or back into a treatment lagoon (See Case Study 3).

If pipelines are above-ground, a condensate collection drum can be set up to self-drain condensate when it has accumulated to a particular level in the drum, thereby requiring little to no human intervention (Figure 3). If below-ground, a condensate collection drum may require a pump to remove condensate on a semi-regular basis (Figure 4). There are off-the-shelf condensate collection drum kits for below-ground use (Figure 4).

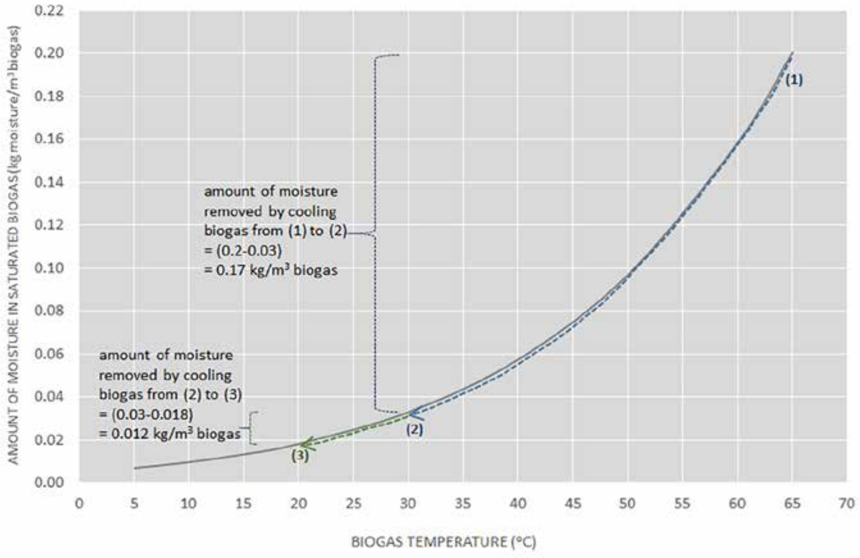


FIGURE 2 An illustrated example of the amount of moisture that condenses when a biogas is cooled from (1) 65°C (temperature under a sun-baked cover) down to (2) 30°C (temperature achieved by contacting biogas with a cool water liquid),and then subsequently in underground pipelines to (3) a soil temperature of 20°C. It is clear that pre-cooling from (1) to (2) can be highly beneficial by removing a lot of the moisture in the biogas.

FIGURE 3 Above-ground condensate collection drums (“knock-out pots”) at Australian piggeries.

(A) Condensate forms a water seal to prevent biogas escaping, but allows condensate to self-drain.

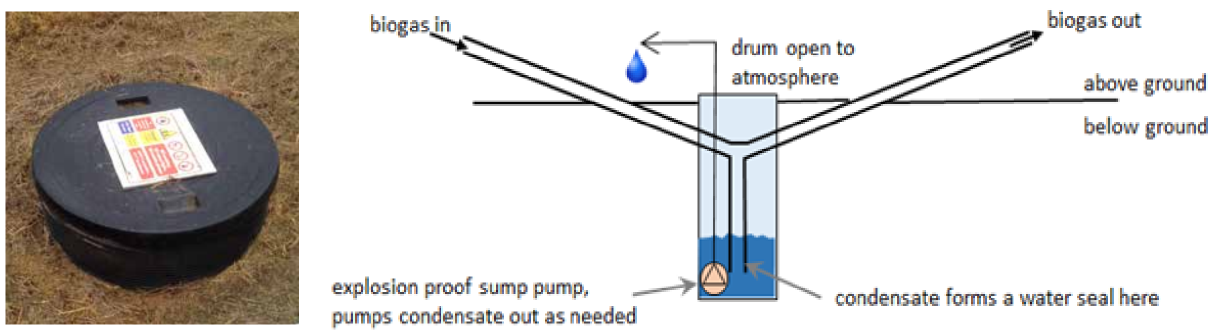
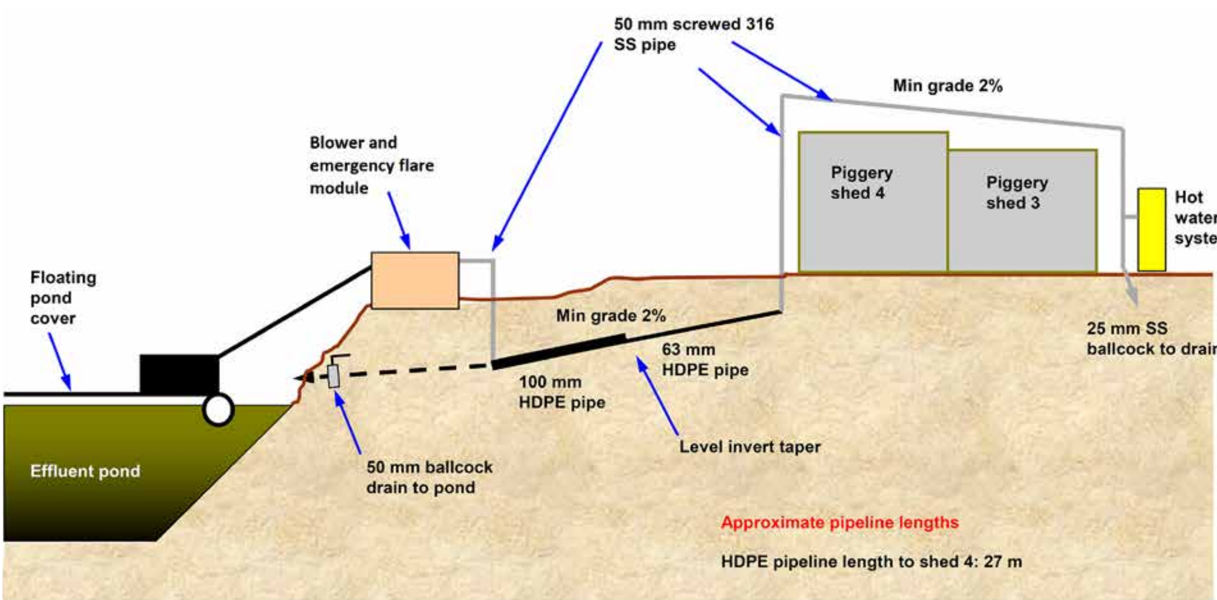


FIGURE 4 Example of a below-ground condensate trap at an Australian piggery. Note that any pump or instrument (e.g. condensate level measurement) used inside a condensate trap needs to be explosion-proof rated in accordance with the relevant requirements. Also, a condensate drum needs to be designed in a way that prevents hazardous exposure to biogas. Note the warning signage on the lid.

CASE STUDY 3

Real Piggery 700 sow Breeder Unit (1370 Standard Pig Units or SPU) QLD

- Conventional flushed sheds
- $259,192 investment in biogas system (2009) – Originally set-up as research system
- Estimate can displace 1606 MJ/day of LPG, potentially saving $23,000/annum
- Floating hood partially covering about 50% of the anaerobic lagoon to capture biogas
- 3.5 kPa pressure provided by biogas blower (fan-type) located near the covered lagoon
- Underground biogas pipelines with 2% slope to drain condensate
- No chiller
- Modified natural gas boiler running on biogas, hot water circulated via heat pads in farrowing house



Schematic adapted from Skerman and Collman (2012), Courtesy RIRDC.
(opposite) Some photos are still-shots from footage courtesy Department of Environment, Commonwealth Government.

Drying of Biogas

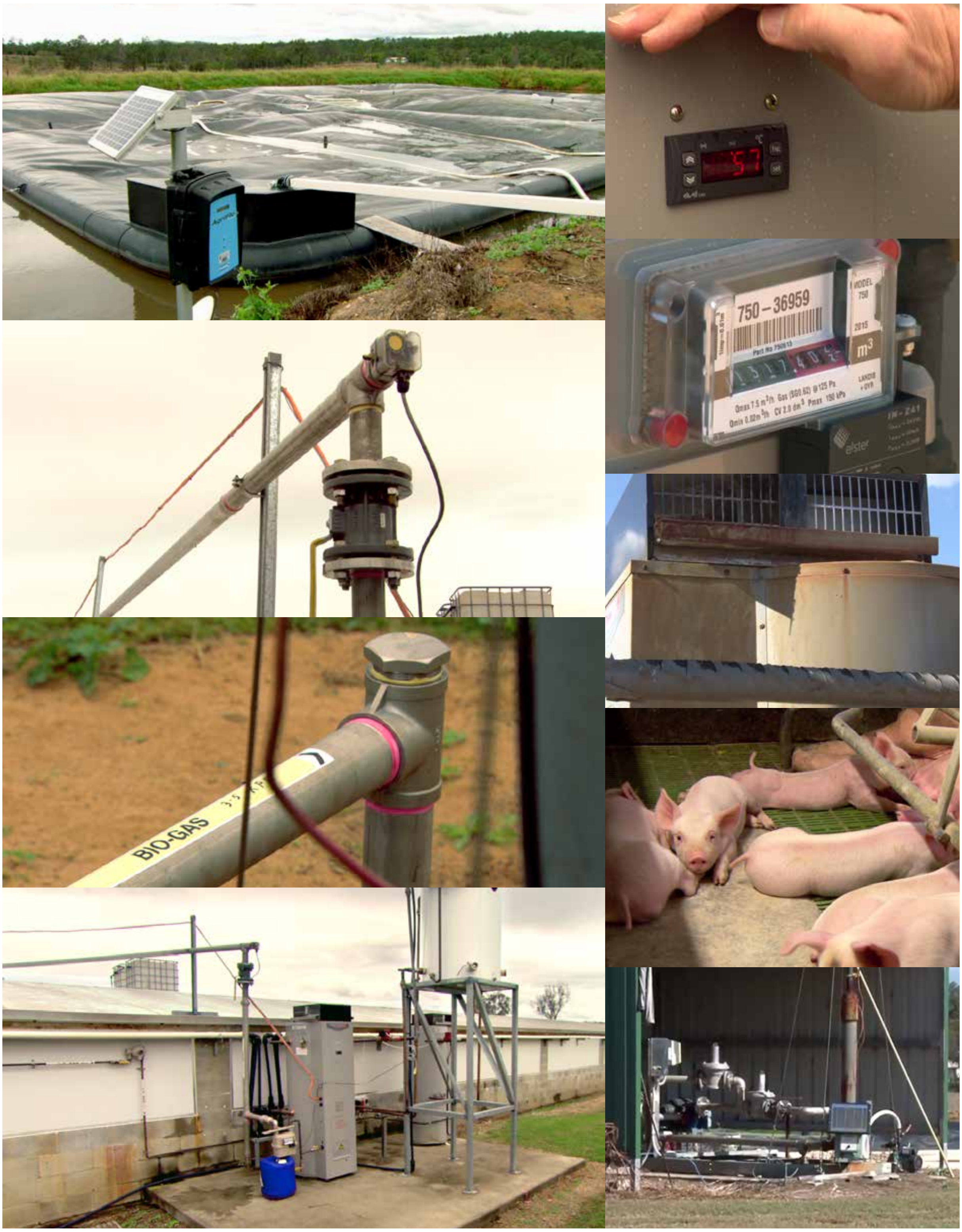


FIGURE Biogas infrastructure at Case Study 3 piggery

Removing Hydrogen Sulphide

Piggery biogas typically contains hydrogen sulphide at concentrations of 500 parts per million by volume (ppm) up to 4000 ppm. Hotwater systems usually require hydrogen sulphide to be less than 1000 ppm and internal combustion engine generators less than 200 ppm. If hydrogen sulphide concentrations are higher, maintenance may be excessive.

Important: Some biogas appliances, such as radiant heaters, should have a vent or flue to discharge exhaust gases to a safe location outside the pig shed. Otherwise, the biogas has to be treated to a much higher quality to prevent exposure of people and livestock to hazardous gases (Skerman and Brown, 2014).

Several treatment technologies are commercially available for hydrogen sulphide (Skerman, 2016). Pork CRC demonstration piggeries are trialling a combination of two treatment steps selected for safe and cost effective operation at piggeries (Skerman, 2016).

These are:

1. biological oxidation, which uses biology and a small amount of added air to remove most of the hydrogen sulphide in biogas; *followed by*
2. chemisorption with iron oxide, iron hydroxide or zinc oxide, which uses chemistry to remove any remaining hydrogen sulphide.

It is important that these treatment steps be in the sequence (1) followed by (2), in order to minimise cost, maximise safety and ensure biogas is treated to a consistent high quality.

Biological oxidation and chemisorption are described in more detail on the pages that follow.

BIOLOGICAL OXIDATION

This treatment uses chemistry and biology with micro-organisms naturally present in pig manure treatment lagoons. The micro-organisms (*Thiobacillus*) convert hydrogen sulphide (a gas) into elemental sulphur (a solid) which is then separated from the treated biogas.

To function, the micro-organisms need moisture, nutrients and some oxygen.

It is important to know how to safely add air to biogas to provide the oxygen needed for treatment (See Case Study 4), because if biogas is mixed with too much air it can create a potentially catastrophic explosive mixture.

Commercial supplier versions are available and include BIOREM® and THIOPAQ®, which have been optimised for many installations.

Pork CRC demonstration piggeries are trialling an alternative that uses the liquid outflow from a secondary dam or grey water storage dam as nutrient source for the biology, so no purchased chemicals are needed (See Case Studies 4 and 6). There has been no attempt to optimise treatment performance at these demonstration piggeries and the systems at these piggeries have required minimal human intervention to date when the biogas flow through the system has been reasonably constant. The treatment performance has been excellent, reducing hydrogen sulphide from 2500+ ppm, to less than 200 ppm in the treated biogas, directly suitable for generator engines and hotwater systems. At the same time, the biogas is being pre-cooled by the nutrient liquid effluent that it comes in contact with, which can greatly reduce moisture in the biogas (Figure 2). Only a small amount of air is added, so methane content in the treated biogas remains high at 50–65% by volume.

The equipment of the biological oxidation step at each of the two Pork CRC demonstration piggeries cost about $20,000 and treats biogas from manure of about 15,000 Standard Pig Units or SPU (150 m^3/hr of biogas flow). The treatment system was largely designed by the piggery owners with guidance from the Bioenergy Support Program and publicly available literature, was pre-fabricated with general off-the-shelf equipment and installed using local labour. The treatment uses a small amount of electricity for a liquid pump (1 kW), but requires a fairly major manual clean-out with fresh water every 10 months or so to remove the solids that had accumulated on a plastic packing inside the treatment vessel (See Case Study 4). This solid may be used as a fertiliser ingredient, but excessive amounts of sulphur can acidify soils. Treating biogas from manure of 15,000 SPU could produce as much as 5–10 tonnes of sulphur per annum (2.5–5 m^3), depending on the hydrogen sulphide content in the biogas.

CHEMISORPTION

Chemisorption is a chemically-based treatment step that removes any remaining hydrogen sulphide after the biological oxidation step. Chemisorption uses a solid raw material (solid medium) that is purchased and has to be replaced semi-regularly (See Case Study 5).

It is best that the biological oxidation step removes most of the hydrogen sulphide before the chemisorption step, so that the chemisorption only has to polish the biogas. In this way, the solid medium requires less frequent replacement, thereby minimising cost.

To further reduce costs, Pork CRC research (Skerman, 2016) investigated the option of chemisorption using Australian ferrous (red) soils mixed with a crop residue such as sugar cane mulch, instead of using purchased commercial media. The red soil contains iron oxide or iron hydroxide that reacts with the hydrogen sulphide in the same way as a purchased solid medium. The red soil performed poorly compared to a purchased medium, but some hydrogen sulphide was removed. A red soil may offer a practical solution for final polishing of biogas after a biological oxidation step. The crop residue was added to reduce the resistance to biogas flow through the red soil, thereby reducing pumping costs.

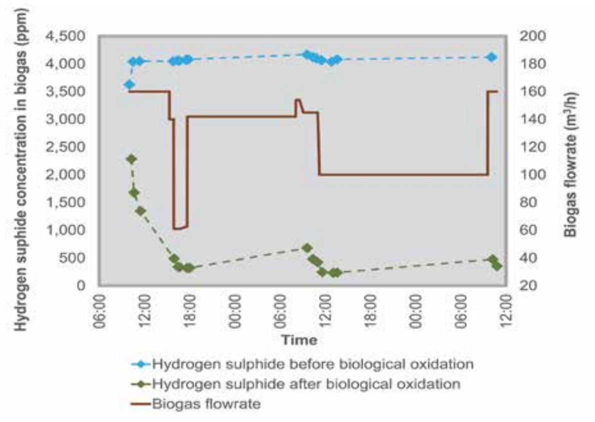
Regeneration of a chemisorption medium. The chemistry of chemisorption can be partly reversed when the solid medium is taken out of the treatment vessel and exposed to air. This is important because in this way the iron in the solid medium can be converted back into the reactive form. This means that the medium can be used in the treatment vessel to remove hydrogen sulphide from biogas, taken out of the treatment vessel to be exposed to air and reverse the chemistry, and then placed back into the treatment vessel for a reuse. In this way, fresh solid medium needs to be purchased less frequently. However, the chemistry is not fully reversed and eventually fresh medium is required.

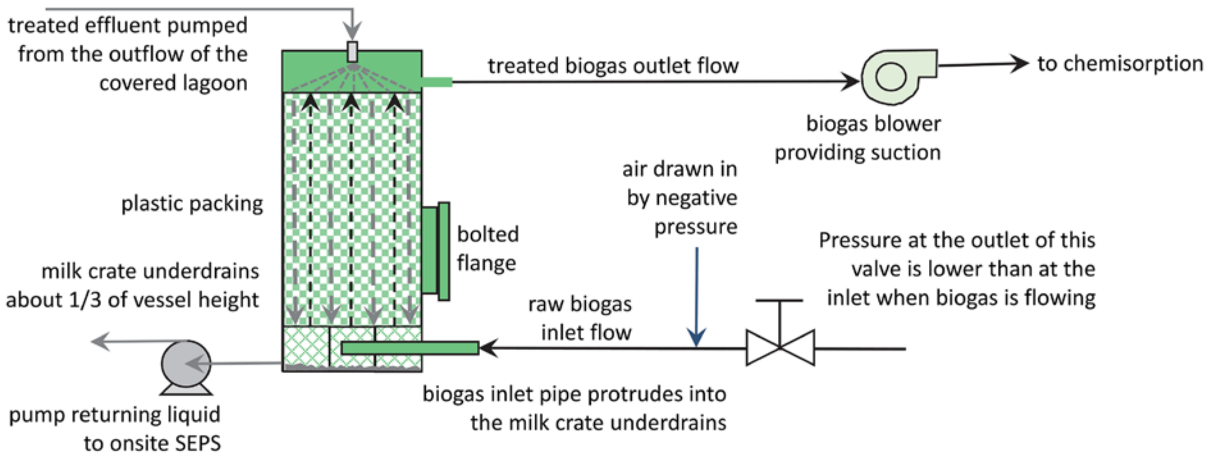
IMPORTANT: A very large amount of heat is released by the chemistry that occurs when used medium is exposed to air. Usually it is recommended that the medium be kept wet before/when exposed to air. This is very important, because it is necessary to keep the medium cool with water, otherwise it can spontaneously burn. If the medium does burn, hazardous combustion products are released, namely sulfur dioxide (SO_2) and sulfur trioxide (SO_3). These combustion products severely irritate the eyes and airways (which would be extremely unpleasant and dangerous) and require sophisticated personal protective equipment and appropriate training for piggery staff to safely perform the change-out of solid medium. Keeping the medium wet circumvents these issues (See Case Study 5). However, experience suggests the design of the treatment vessel is extremely important, to allow easy and safe access when replacing the solid medium. Specifically, when wetted the solid medium tends to clump together and would be more difficult to remove from a treatment vessel with inadequate access.

CASE STUDY 4

Same as Case Study 1 with Biological oxidation details

- Equipment for the biological oxidation step cost about $20,000 (See schematic)
- Air is drawn into the biogas pipeline at a tapping saddle before the treatment vessel. The amount of air is around 4 m^3/h, which is roughly 2.5% to 6% of the total biogas flow of 60–150 m^3/h.
- Air is drawn in only when biogas flows through the pipeline, creating a slight negative pressure at the tapping saddle. This prevents explosive mixtures of air and biogas.
- Nutrients provided by recycled treated effluent from a covered lagoon nearby, which is sprayed over the top of an inert plastic packing in the treatment vessel.
- The biological oxidation reduces hydrogen sulphide from 4000+ ppm down to less than 400 ppm in single treatment step.





Removing Hydrogen Sulphide

FIGURE Biogas infrastructure at Case Study 4 piggery

SEPS is Sedimentation and Evaporation Pond System

Repeated physical skin contact with elemental sulphur may cause irritation. Consult Material Safety Data Sheet.

(A) Covered lagoon outflow pit from where effluent is recycled to the treatment vessel.
(B) Biological oxidation (treatment) vessel.
(C) Unused inert plastic packing.
(D) Used plastic packing filled with solid accumulated because of the biology and chemistry occurring in the treatment vessel.
(E) For safety, a pipe extends the port, through which air is drawn, to above head-height.

CASE STUDY 5

Same as Case Study 3 with Details of a Change out of chemisorption medium

- When biogas wasn't being treated, hydrogen sulphide caused severe maintenance problems
- During a research trial, chemisorption was tested. The treatment vessel was made of U-PVC with a bolted flange lid. The treatment reduced hydrogen sulphide from 1,000+ ppm down to nil.
- The solid reagent medium was changed out during the trial, BUT the bed of medium in the treatment vessel was completely flooded with water BEFORE the change-out, to keep the medium cool when exposed to air, and thereby making the change-out much safer.

Removing Hydrogen Sulphide

FIGURE Biogas infrastructure at Case Study 5 piggery

(A) Hotwater system without chemisorption.
(B) With test chemisorption system installed.
(C) Iron oxide pellets in treatment vessel **before** reacting with hydrogen sulphide.
(D) The same iron oxide pellets after reacting with hydrogen sulphide before change-out.
(E) Damage to burner by hydrogen sulphide.
(F) Water droplets on the flange rim. The medium was completely flooded **before** the vessel was opened for the change out.
(G) The medium being tipped out onto a metal tray.
(J) The medium being spread out on the tray and plastic plenum pieces recovered. No off-gases were noted.

Some photos Courtesy RIRDC (2012).

Concluding Remarks

Three Pork CRC demonstration piggeries are treating biogas to remove hydrogen sulphide, using chemisorption with commercial iron oxide pellets, and two of these use biological oxidation to remove most of the hydrogen sulphide before the chemisorption (See Case Study 6).

Other Australian piggeries are also implementing biological oxidation. The biological oxidation step also removes much of the moisture in the biogas by pre-cooling it. After biological oxidation and chemisorption, hydrogen sulphide in the biogas is essentially nil and the biogas is highly suitable for use as a fuel for a generator or hotwater system.

AN IMPORTANT SAFETY REMINDER

Biogas is dangerous if not handled correctly. Biogas can be explosive and hydrogen sulphide in biogas is extremely toxic. Talking Topic 2 and the *Code of Practice for On-farm Biogas Production and Use at Piggeries* (Yap et al., 2015) describes practical approaches to safely handle biogas.

CASE STUDY 6

Real Piggery 2000 sow Farrow-to-Finish VIC

- Conventional flushed sheds and unmixed covered lagoons
- $900,000 investment in biogas system. Anticipate a further $800,000 of investment to be completely energy self-sufficient.
- Estimate $240,000 income to date from sale of carbon credits
- Estimate can use biogas to displace 633,366 kWh per annum electricity and 44,744 L per annum of LPG, potentially worth $390,000 per annum
- Biogas treatment includes biological oxidation (green tank in figure), followed by chemisorption (steel tank in figure), followed by a 6 kW electrical chiller unit (horizontal silver heat exchanger, with black and orange chiller unit in Figure), followed by a blower to boost biogas pressure to 5 kPa, followed by a 1 km long underground pipeline with one condensate collection drum along the way to a 54 kWe generator.
- The chiller unit has never been used, fully relying on pre-cooling in the biological oxidation step, followed by passive cooling of biogas in underground pipelines.
- The chemisorption step is currently by-passed (not used) because the biological oxidation step achieves hydrogen sulphide concentrations of less than 200 ppm, suitable for a generator.

FIGURE Biogas treatment infrastructure at Case Study 6 piggery

Other Talking Topics

Talking Topic 1
Collecting the biogas benefits of pig manure

Talking Topic 2
Biogas safety – The essentials

Talking Topic 3
Covered lagoons

Talking Topic 4
Cleaning piggery biogas
This present document

Talking Topic 5
Using piggery biogas

Talking Topic 6
Reducing the carbon footprint of a piggery

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3. Skerman, A.G. and Collman, G. (2012). *Methane Recovery and use at Grantham Piggery.* RIRDC Publication No. 12/064, RIRDC Project No. PRJ-005672.

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