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Assessing the Medium-Term Impact of Permeable Pond Covers on Pond Performance and Odour Management – Monitoring Phase

Final Report
APL Project 2002/1829

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Project Commencement and Completion

Project commencement: date:	29/08/07
Project completion date:	23/03/09

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Executive Summary

This project was an agreed extension to the original APL project 1829, 'Assessing the medium-term impact of permeable pond covers on pond performance and odour management'. The aim of this extension was to undertake a further study into the ongoing performance of the pond cover at Piggery C, in terms of its ability to continue to reduce odour emissions as well as its ongoing durability and integrity.

The key findings from this extension support the original findings of project 1829, in that permeable pond covers are an effective tool in reducing odour emission rates from anaerobic ponds. Tensile tests undertaking on the cover material during this extension project demonstrate that the polypropylene material has degraded. Results indicate that the material would be more likely to tear, and that tears would be easier to propagate once started. This aspect has particular relevance in situations where the cover requires handling, such as has for pond maintenance or desludging. This extension trial found that using shadecloth only as a pond cover has significant potential to reduce odour emission rates, demonstrating it to be a lightweight, cost effective material for deployment on anaerobic ponds to act as an odour reduction tool, as odour reduction rates were similar to polypropylene covers.

This extension trial initially had a duration of three years, however APL requested reduction of the monitoring phase to 18 months.

1. Introduction

1.1. Background

In response to the ongoing problem of odour from intensive piggery operations impacting on nearby receptors, Australian Pork Limited (APL) funded a research project led by the Queensland Primary Industries and Fisheries (QPIF) to investigate an effective odour management strategy. An initial investigation by Hudson *et al.* (2001), on behalf of APL, identified that permeable pond covers may be a tool to assist in reducing odours emitted from anaerobic treatment ponds. This preliminary research indicated that odour emitted from pond surfaces could be reduced by at least 50%, based on lab–scale studies, and up to 90% based on field–scale studies.

In 2002, APL commissioned QPIF to undertake a three year research project to investigate the potential of permeable pond covers as a tool to reduce odour and gas emissions from anaerobic treatment ponds. This research project assessed the efficacy of a permeable polypropylene geotextile cover and a supported straw cover in their ability to reduce odour and gas emissions, as well as the durability of these materials once installed.

At the conclusion of the original three year research period (concluded December 2006), the key findings were:

- Permeable pond covers were identified as a cost effective method to reduce odour emissions from anaerobic treatment ponds.
- The combination of polypropylene and shadecloth covers resulted in an odour emission rate (OER) reduction of 76% (internal comparison1) and 50% (external comparison2).

[1] Internal comparison—comparing OER of samples derived from pond cover to OER of samples derived from exposed liquor surface of the same covered pond.

- Straw covers resulted in an odour reduction of 66% (internal comparison). However, it was discovered that straw covers have a limited life (approx 12 months) before requiring further straw material.
- An unexpected finding was the effectiveness of shadecloth as an odour reducing cover. Due to ultraviolet radiation degradation of the polypropylene covers, shadecloth was installed over the geotextile material. A window was cut out of the geotextile thereby allowing shadecloth to cover the liquor surface. Testing on this area indicated that 'shadecloth only' reduced emission rates by more than 60% (relative to exposed liquor).
- No significant effect on pond chemistry was detected. pH, chemical oxygen demand (COD), and volatile solids (VS) were not affected by cover installation. Discharge from a covered pond did not contain greater concentrations of under treated waste material which could lead to an increasing loading rate on a secondary or facultative pond.
- At APL's request, an investigation was undertaken into utilising effluent from covered ponds–for irrigation or as a flushing medium. There was no significant difference in odour emission rates from pasture irrigated with effluent from a covered pond compared to pasture irrigated with effluent from an uncovered pond. Using a housing model, it was demonstrated that odour emissions were not significantly higher with effluent derived from a covered pond to effluent from an uncovered pond.

To test the stability of polypropylene based pond covers, APL extended the trial to monitor the on-going performance of a polypropylene-shadecloth cover located at Piggery C, commencing in June 2007, and concluding in July 2008. This testing involved biannual sampling from the cover for odour emission and cover material structural integrity. This report is a summation of the results obtained during the monitoring period.

1.2. Aims/Objectives

The key objectives of the monitoring phase were to:

1. Assess the effectiveness of permeable pond covers for reducing odour emitted from piggery ponds over a three year period at Piggery C;
2. Evaluate the longevity of the cover material by conducting periodic material tensile strength tests on samples obtained from the installed cover at Piggery C.

2. Methodology

A biannual sampling regime was established to collect odour and material samples from Piggery C. Samples were planned for collection during Winter, Summer, then again in Winter, assessing both cover impact as well as seasonal impacts on odour reduction/generation.

2.1. Odour Sample Collection

On each odour sampling day, four sets of duplicate samples were collected using the QPIF wind tunnel, as outlined in Table 1. These duplicate samples were comprised of four duplicate pairs:

- one pair from the combined shadecloth + polypropylene cover,
- one pair from the 'shadecloth only' cover,
- one pair from the liquor surface of the control (uncovered) pond, and
- one pair from the exposed liquor of the covered pond.

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[2] External comparison—comparing OER of samples derived from covered pond to OER of samples derived from a nearby uncovered pond.

The duplicate samples were obtained by simultaneously collecting the samples across two sampling drums.

Table 1: Odour sampling dates and sample collection points

Odour Sampling Date	Sampling site
29/08/2007	Shadecloth + polypropylene
29/08/2007	'shadecloth only'
29/08/2007	Exposed Liquor
29/08/2007	Liquor Surface – Control Pond
27/11/2007	Shadecloth + polypropylene
27/11/2007	'shadecloth only'
27/11/2007	Exposed Liquor
27/11/2007	Liquor Surface – Control Pond
11/07/2208	Shadecloth + polypropylene
11/07/2008	'shadecloth only'
11/07/2008	Exposed Liquor
11/07/2008	Liquor Surface – Control Pond

Odour samples were collected using the UNSW style wind tunnel, described in Hudson *et al.* (2007). Samples were analysed in the QPIF eight panellist, triangular, forced choice dynamic olfactometer, conducted and operated in compliance with the requirements of the Australian/New Zealand Standard for Dynamic Olfactometry–AS/NZS 4323.3:2001 (Standards Australia, 2001).

The impact of the permeable cover in reducing odour emission rate was determined through both an internal comparison and an external comparison of odour emission rates. An internal comparison is defined as a comparison of OER results obtained from the cover surface (either polypropylene+shadecloth or 'shadecloth only') to those OER results obtained from the exposed liquor of the same covered pond. An external comparison is defined as a comparison of OER results obtained from the covered pond (either polypropylene+shadecloth or 'shadecloth only') to the OER results from the liquor surface of the control pond.

2.2. Site Details and Management Practices

Piggery C was operated as a breeder-grow out unit, with one third of the pigs born on site raised until sent to market and the remainder sent off-site for finishing. Animals were housed in nine fully slatted sheds. All flushing and hosing water was derived from municipal supply. Hosing occurred every second day, while flushing took place weekly. Approximately 2,400 animals were housed on site at any time. Waste was discharged to a pipeline that contained a splitter box. This diverted approximately half of the waste load and volume to each of two similarly sized anaerobic ponds (40 m x 35 m). Excess liquor discharged from each pond into a single secondary pond. Each primary pond experienced a waste loading rate of about 50 g VS/m^3/day. The parallel configuration of the two anaerobic ponds was very fortuitous – it allowed one pond to be covered and the other to be left uncovered as a control (Hudson *et al.* 2007).

During the course of the monitoring trial, these practices changed, but were only disclosed following the conclusion of the June 2008 sampling event. With the piggery sourcing its water from the municipal supply, the ongoing severity of the drought forced the piggery manager, in approximately September 2007, to significantly reduce water usage by altering the flushing schedule, from once/week to a static pit operation, with flushing once every 6 weeks. Hosing had not been altered. Furthermore, the manager had also introduced an enzyme based product claimed to assist in the breakdown of solid material and in the reduction of odour. This product was added directly to the underfloor static pits once every 6 weeks.

2.3. Cover Material Sample Collection

Prior to odour sampling events, a section of the polypropylene pond cover measuring approximately 4 m by 4 m was cut out of the cover, washed thoroughly, then sent to a commercial materials testing laboratory. Strength tests were conducted on the material, namely:

- Determination of tensile properties–wide strip method (AS 3706.2), 5 replicates per direction
- Determination of trapezoidal tear strength (AS 3706.3), 10 replicates per direction
- Determination of burst strength–California Bearing Ration (CBR) plunger method (AS 3706.4), 10 replicates per direction
- Determination of puncture resistance–Drop cone method (AS 3706.5), 10 replicates per direction
- Determination of maximum force and elongation using strip method–narrow strip method (AS 2001.2.3.1–2001), 10 replicates per direction.

During the monitoring phase, three samples of material were collected from the permeable cover installed at Piggery C. Prior to this testing, only one other sample had been analysed for tensile strength properties, which occurred in August 2005.

3. Results and Discussion

3.1. Assessment of Odour Emissions from Pond Covers

Over the 18 month assessment period, 18 samples were collected from the covered pond, and six from the nearby uncovered pond. Table 2 presents the results from these assessments. Results presented are an average of a duplicate pair. Figure 1 shows a graphical representation of the odour emission rates from the various sources for the duration of the monitoring phase.

Table 2: Summary of odour emission rates from Piggery C – July 2007 to June 2008.

Source	Concentration (OU/m³)	Odour Emission Rate OU/m²/s	Hedonic Tone[A]
August 2007			
Covered Pond (shadecloth+polypropylene)	84	6.6	-1.65
Covered Pond ('shadecloth only')	376	29.55	-2.05
Covered Pond (exposed liquor)	777	61.1	-1.95
Uncovered Pond (Control pond)	704	55.3	-2.45
November 2007			
Covered Pond (shadecloth+polypropylene)	113.5	7.95	-1.4
Covered Pond ('shadecloth only')	157.5	11.15	-2.15
Covered Pond (exposed liquor)	501	35.25	-2.75
Uncovered Pond (Control pond)	62	5.3	-1.8
July 2008			
Covered Pond (shadecloth+polypropylene)	180.5	13.85	-1.8
Covered Pond ('shadecloth only')	113	9.2	-1.9[B]
Covered Pond (exposed liquor)	786	66.1	-2.65
Uncovered Pond (Control pond)	25	2	[C]

Notes: A: Hedonic tone scale is -4 (extremely unpleasant) to 0 (Neutral) to +4 (extremely pleasant). This non-standard method, adapted from the VDI 3882 Standard, has been developed by the SIS group of QPIF.

B: Only one sample analysed for hedonic tone. Other sample expired before fully analysed.

C: No samples analysed as both samples expired before completing hedonic tone analysis.

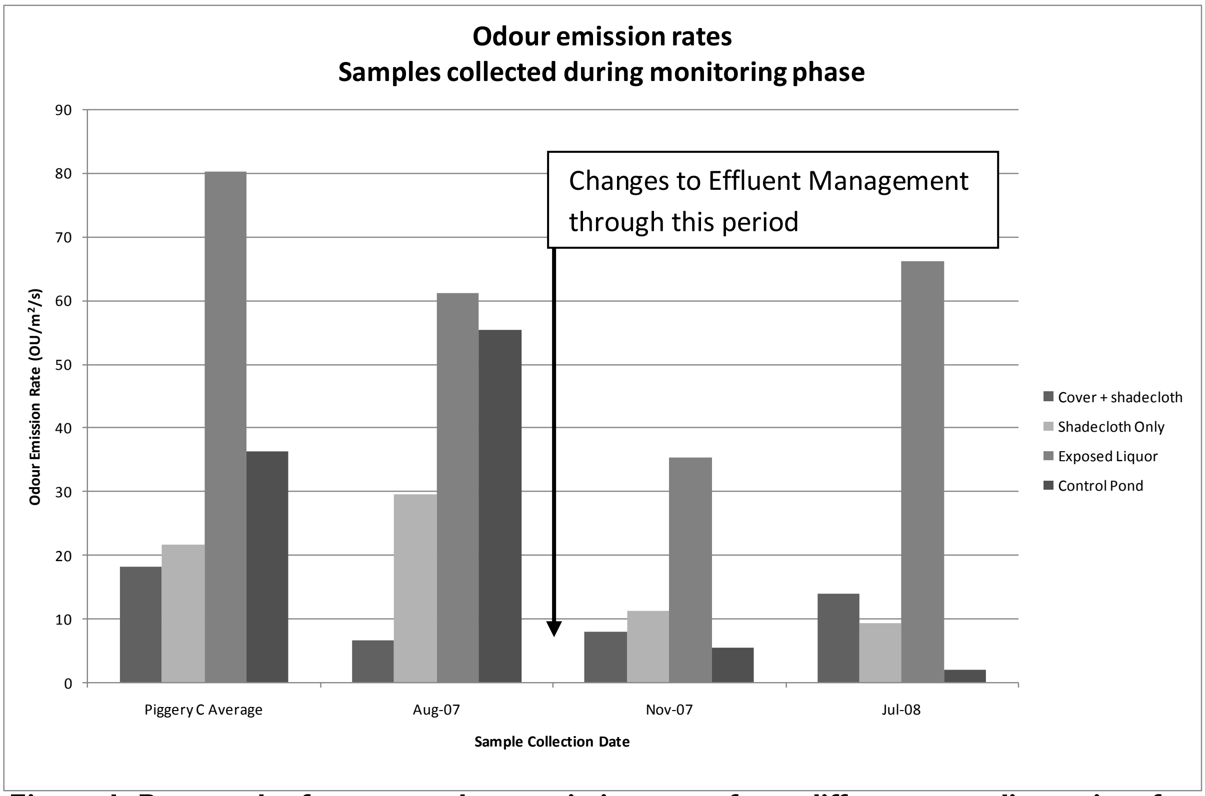

Figure 1: Bar graph of average odour emission rates from different sampling points for the three sampling events at Piggery C over the course of the monitoring phase. Overall average odour emission rate for Piggery C, determined from results obtained during initial three year project, is also presented (excludes monitoring phase results).

3.2. Effectiveness of Geotextile Covers at Reducing Odour Emissions

Hudson *et al.* (2007) found that the combination of polypropylene and shadecloth reduced odour emissions by up to 77%, and 'shadecloth only' reduced odour emissions by up to 73% (both via internal comparison). In comparing the uncovered pond nearby, the shadecloth and polypropylene cover reduced odour by 50% and the 'shadecloth only' cover reduced odour by approximately 40%. The shadecloth+polypropylene cover OER and 'shadecloth only' cover OER were quite low at the beginning of the monitoring trial (Figure 1), and compared favourably to results obtained by Hudson *et al.* (2007). As seen in Table 2, the OER and concentration from the control pond was quite low for samples collected in November 2007 and July 2008, and could conceivably be considered as background odour–that is, odour levels normally detected in the atmosphere. Further investigation at the conclusion of the June 2008 sampling event, revealed the significant changes in management practice, as described in section 2.2. It is difficult to determine whether these management changes directly contributed to the reduced emission rates from the control pond. The utilisation of a static pit and reduced flushing may have resulted in most anaerobic breakdown occurring in static pits under the piggery sheds. Also, the inclusion of the enzyme based product to the pits to accelerate waste breakdown, would increase OERs pre-pond.

As noted by Hudson *et al.* (2007), other contributing factors to a change in odour emission rates from the covered pond include hydrogen sulphide concentration and the increased biological activity on the cover material. Effluent samples from a covered pond exhibit an increase in hydrogen sulphide concentration in the liquor, until an elevated equilibrium is reached. It was also demonstrated that hydrogen sulphide emission rates for the covered pond were significantly higher than those measured from the control pond. Hudson *et al.* (2007) also postulated that an increase in biological activity on the cover, due to an increase in micro-flora and fauna, vegetation (grass growth), and rotting detritus, may lead to changes in odour emission rates and odour composition.

A surprise finding from the initial three year project was the effectiveness of just shadecloth at reducing odour emissions. It reduced odour on average over the entire three year period by 65% to 77% (intra–pond comparison). Similarly, during the monitoring phase it reduced odour by greater than 52%, with a maximum reduction of 88% (by intra pond comparison) at the conclusion of the trial in June 2008.

3.3. Assessment of Tensile Strength of Geotextile Material

The tabulated results are the average values derived from the number of replicates described in section 2.3.

Table **3** presents the results obtained from the tensile strength tests during the monitoring phase, together with the results obtained from August 2005. The tabulated results are the average values derived from the number of replicates described in section 2.3.

Table 3: Results obtained from tensile strength testing for geotextile material recovered from Piggery C.

	Determination of tensile property - Ultimate Tensile Strength (using wide strip method) (kN/m)		Determination of tensile property - Elongation (using wide strip method) (%)		Determination of maximum force - narrow strip method (N)		Determination of maximum elongation - narrow strip method (%)		Trapezoidal tear strength (N)		Bursting strength - CBR method (N)	Bursting strength - CBR method elongation %	Puncture resistance - drop cone method		
Sample source	**MD**	**CMD**	**MD**	**CMD**	**MD**	**CMD**	**MD**	**CMD**	**MD**	**CMD**			**Puncture diameter d500 (mm)**	**Puncture diameter d1000 (mm)**	**Puncture resistance h50 (mm)**
Original specifications	31.5		-*		1875		-*		875		7455	-*	-		
August 2005	21.3	33.6	49	52	1174	1080	44	48	602	820	4499	38	12	19	4130
August 2007	25.4	31.8	56	54	1071	1544	56	53	587	846	5718	39	12	20	4100
November 2007	14.7	25.5	49	50	689	881	49	47	379	612	3898	35	16	33	2960
July 2008	19.2	33.7	60	62	971	1321	53	52	490	715	3901	40	17	28	2480

Notes: A: These tests were conducted under AS 3706.5-2000. Tests conducted in August and November 2007 were conducted under AS 3706.5-2001.

∗ Typically, nonwoven geotextiles have a breaking elongation when new of between 40% and 80% (www.syntheticpackaging.com/Index.php?Page=Geotextiles).

MD: machine direction – the direction in a machine-made fabric, parallel to the direction of motion of the material through the processing machine i.e. along the length of the roll (Maccaferri, 2008).

CMD – cross machine direction - the direction in a machine made fabric, perpendicular to the direction of motion of the material through the processing machine i.e. across the width of the roll (Maccaferri, 2008).

3.4. Durability of Polypropylene Pond Covers

During the three year research trial, only one set of samples from the polypropylene covers were collected and analysed for strength properties. Hudson *et al.* (2007) concluded from these results that the cover material had degraded considerably since installation, and inferred that these changes were due to UV degradation caused by extended exposure to sunlight.

From Table 3, it can be seen that the geotextile pond cover material has degraded from its original specification. The tensile property tests, both wide strip and narrow strip, indicate that the geotextile is becoming easier tear, requiring less force to initiate a tear, and less force to propagate the tear. This degradation is also supported by the puncture tests, as the material is now becoming easier to puncture (ie requires less force to rupture the fabric), and that generated punctures are becoming larger. Whilst Table 3 demonstrates via the results of the various tensile test that the material has shown degradation, an ANOVA analysis was undertaken to determine how significant the degradation is from testing undertaken in August 2005. This analysis indicated that the results obtained from August 2007 were significantly different to all others for the test of CBR burst strength (higher), puncture resistance (drop cone h50) (higher), and puncture diameter (d500)(lower). Furthermore, only two results obtained from the November 2007 samples indicated a significant difference to all others, namely the breaking force machine direction test (lower) and the trapezoidal tear test in machine direction (lower). It can be concluded that the material has changed significantly from deployment, and from the testing in August 2005, in that its tensile properties have degraded. A comparison between the November 2007 sample and the June 2008 sample reveal only a significant difference between two results (both lower), as mentioned previously. Other properties reveal no significant difference.

Degradation of tensile properties, as indicated in Table 3, is of particular importance if the cover requires handling. As the results indicate that the material will be more prone to tearing, and that tears will spread and continue easily, handling covers to undertake pond maintenance, or to remove the cover for pond desuldging, will require great care.

As can be seen from Table 3, the results appear to increase after November 2007. As mentioned by Hudson *et al.* (2007), material for the pond covers was supplied commercially on a 4 m by 60 m roll. Fabric lengths were then sewn together to create a series of cover units, which were then deployed on the pond. It is possible that these cover units not only consisted of material from different rolls, but also from different batches. This may explain the apparent increase in tensile strength results and highlights the difficulty in obtaining a 'representative' sample from a cover that is approximately 1400 m^2 in size.

During both the initial project period and the monitoring phase, no strength tests were undertaken on the shadecloth material. As the shadecloth was installed as a protective cover, it was never regarded as a sole odour reducing cover. The material selected was an open weave polyethylene shadecloth, with a 95% shade factor. This material is designed to be installed in areas exposed to high levels of sunlight and has an extended life expectancy. Based on these facts, it was deemed unnecessary to undertake strength tests on the material. Observations by the QPIF field sampling team indicated that the shadecloth was quite durable, exhibiting minor signs of wear and tear, such as holes.

One significant observation was the noticed failure of some cable ties—used to tie the strips of shadecloth together—due to UV degradation. In areas where the cable ties had failed, the shadecloth was blown away from the polypropylene, thereby exposing large areas of geotextile material. This is a significant issue as once the ties begin to fail, pressure applied by wind forces to the cover can exceed what the remaining ties can withstand. This may result in complete cover failure due to the shadecloth strips tearing apart, or due to wind being able to get beneath the shadecloth and lifting it off the polypropylene. This was highlighted by Hudson *et al.* (2007) (refer to Figure 36) and Duperouzel (2008) (refer to figures 2 and 3).

4 Conclusions and Recommendations

4.1 Conclusions

1. This extension has reinforced the original findings of APL 1829, reported by Hudson *et al.* (2007), that polypropylene covers are an effective tool in reducing odour emission rates from anaerobic ponds.
2. 'Shadecloth only' covers had a significant effect in lowering emission rates from anaerobic ponds. Based on internal comparison, a 'shadecloth only' cover reduced emission rates by up to 88%. Shadecloth may prove to be a lightweight, cost effective material for deployment on anaerobic ponds.
3. Tensile properties had altered since installation, but had only considerably degraded in two areas since initial testing in August 2005. Hudson *et al.* (2007) reported significant degradation within 12 months after deployment, possibly due to excessive UV exposure. Testing during this trial have demonstrated that properties had changed since testing in August 2005, potentially leading to an increased likelihood of damage when handling the cover, such as for pond maintenance or desludging.

4.2 Recommendations

1. Polypropylene covers, due to their instability under UV radiation, if used, require covering with another material, such as shadecloth (it should be noted that these covers were installed some five years ago). It may be the case that geotextile technology has advanced since then, possibly leading to materials that are more stable under UV radiation. This warrants further investigation.
2. Further investigation into 'shadecloth only' covers is necessary to ascertain their suitability at lowering emission rates because they may prove to be a more cost effective option. This trial has demonstrated they significantly reduce emission rates, almost to levels of the geotextile. Shadecloth is a much easier material to handle, has stronger UV resistance, and less expensive than geotextile. It should be noted that this trial only investigated small 'windows' of shadecloth over the liquor surface–no entire pond was ever covered with shadecloth.
3. Vegetation around ponds needs to be carefully maintained. During the monitoring phase, it was observed that over short periods of time, vegetation can quickly establish on the cover. This can lead to damage caused by grass roots, accumulation of detritus, and may lead to cover submergence. This aspect is especially critical if employing 'shadecloth only' covers.
4. Further investigation of additives and waste handling methods is recommended. This trial observed significant reductions in odour emissions from the control pond, coinciding with the use of an enzyme based additive and changed liquid handling practices. Given the lengthy research period at this piggery, a significant database exists of emission rates and concentrations, enabling further research to be readily conducted.

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