Waste Water Management

IN THE AUSTRALIAN RED MEAT PROCESSING INDUSTRY

MINTRAC

AMPC

INSIDE FRONT COVER

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Waste Water Management

IN THE AUSTRALIAN RED MEAT PROCESSING INDUSTRY

GUIDELINES FOR THE DAY-TO-DAY MANAGEMENT AND OPERATION OF:

- UPSTREAM WASTE WATER TREATMENT
- ANAEROBIC PONDS
- METHANE GAS CAPTURE SYSTEMS
- AEROBIC PONDS

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INTRODUCTION

This Training Kit is a joint effort between MINTRAC and the Australian Meat Processor Corporation Ltd. Its development was funded by the Australian Meat Processors Corporation (AMPC) and the Environment and Biotechnology CRC (EBCRC).

The kit can be used as a resource for accredited and in-house training as well as being a manual for Wastewater treatment operators. It contains guidelines for the day-to-day management and operation of:

- upstream wastewater treatment
- anaerobic ponds
- aerobic ponds
- biogas gas capture systems.

Inside this kit you will find:

- Training materials including:
- an overview of each aspect of wastewater operations at meat processing facilities
- legislative and regulatory requirements governing the operation and maintenance of wastewater management systems
- operation and maintenance of wastewater processes
- available training programs for accreditation of staff, in-house training, and continual professional development
- case studies/examples of the management and operation of the wastewater treatment processes
- Trainer information.
- Glossary.
- ePub version of the kit.

GLOSSARY

TECHNICAL TERM	EXPLANATION
Green streams	Green stream wastewater is generated from manure and paunch wastes, which come from stockyard washing, emptying of the animal stomachs and further processing of internal organs.
Red stream	Red stream is generated mainly from water used to guarantee modern hygienic practice in the facility, and which becomes contaminated with blood and fats – primarily from the slaughter and evisceration areas.
ACRONYM	**MEANING**
TS	Total solids
DAF	Dissolved Air Flotation
kPa	kilopascals
COD	Chemical Oxygen Demand
EPA	Environmental Protection Authority
CALs	Covered Anaerobic Lagoons
BOD5	Biological Oxygen Demand over five days
TSS	Total Suspended Solids
NGERS	National Greenhouse and Energy Reporting System
VFA	Volatile Fatty Acids
TA	terephthalic acid
TKN	Total kjeldahl nitrogen
DO	Dissolved oxygen
VOC	volatile organic compounds
RIRDC	Rural Industries Research and Development Corporation
SCADA	supervisory control and data acquisition
EPA	Environment Protection Authority

Waste water training material

UPSTREAM WASTE WATER TREATMENT

Overview of upstream treatment

The treatment of raw waste water from meat processing plants needs to be a sequential process. Upstream treatment is the first set of treatment processes. Its task is to prepare the waste water for:

- discharge to sewer
- further treatment using biological treatment processes.

For this reason, the upstream processes are often described as primary treatment.

Meat processing waste water can be difficult to treat properly compared to other industrial waste waters. This is due to the following characteristics.

High total suspended solids levels

Typically raw waste water has high concentrations of suspended solids, particularly in green streams. These suspended solids arise from paunch emptying and intestine or runner operations and from stockyards, in the form of grit or sheep pellets. If not removed during upstream treatment, these solids settle out in ponds and fill them rapidly.

High oil and grease concentrations

The waste water is usually rich in oil and grease which disturbs biological treatment processes and produces floating scums and crusts in downstream pits, basins and ponds. This is especially the case where rendering is part of the facility.

High temperatures

It is common to measure temperatures as high as 50 – 60°C in red waste streams from meat plants, especially where rendering is part of the facility. This is too hot for biological processes (these prefer less than 35°C). High temperatures also emulsify oils and greases into the waste water resulting in poor separation in savealls and dissolved air flotation units.

These three characteristics complicate biological treatment of meat processing waste water. They are the main reasons for the failure in meat processing applications of intensive biological treatment processes commonly seen in other industries.

The upstream, or primary, treatment processes used in the meat processing industry typically seek to do one of three things:

1. reduce suspended solid concentrations
2. reduce oil and grease concentrations
3. dampen variations in flow

The next sub-sections explore each of these in turn. Figure 1 shows a schematic diagram of how the various upstream processes may be applied to a meat plant.

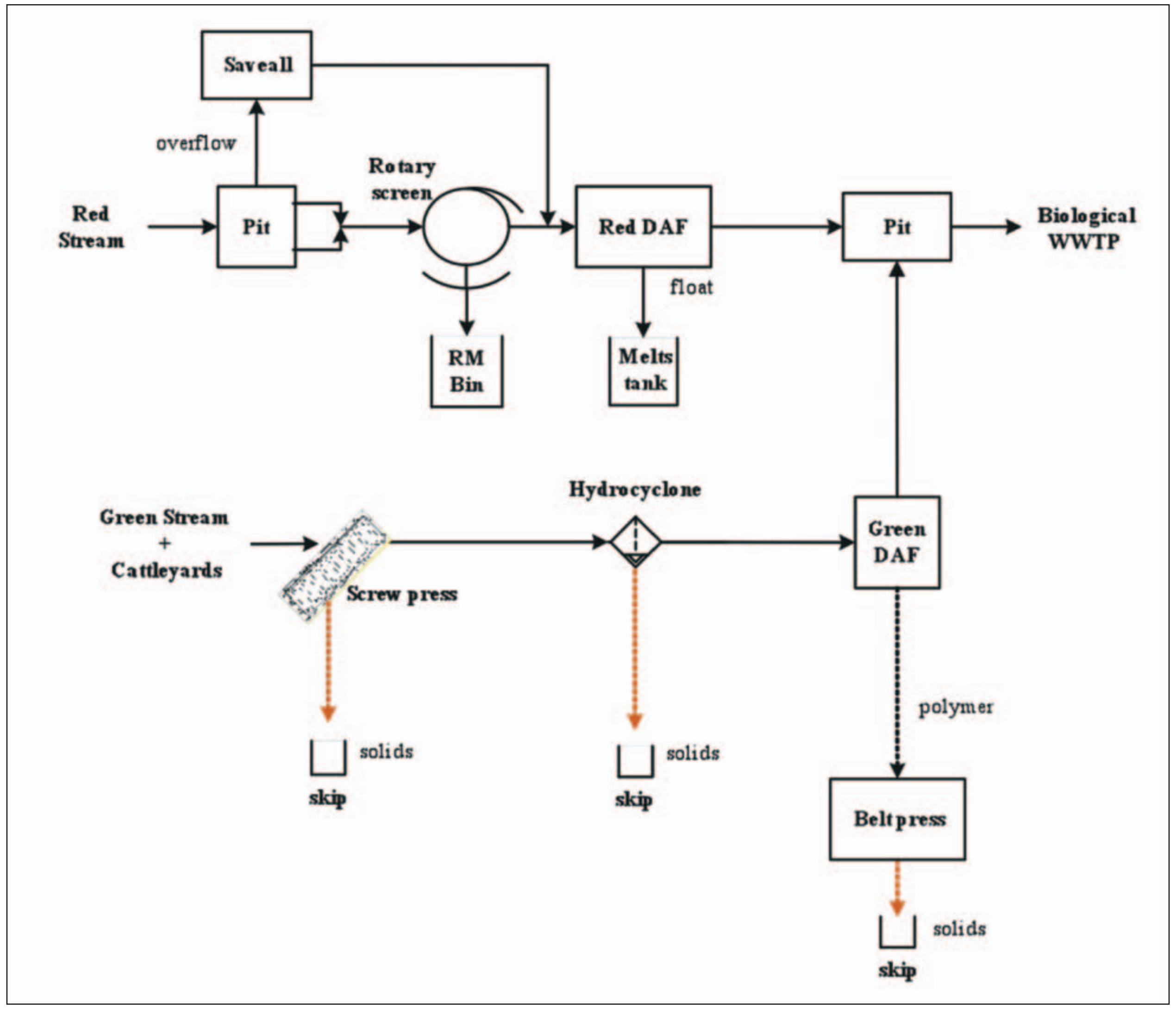
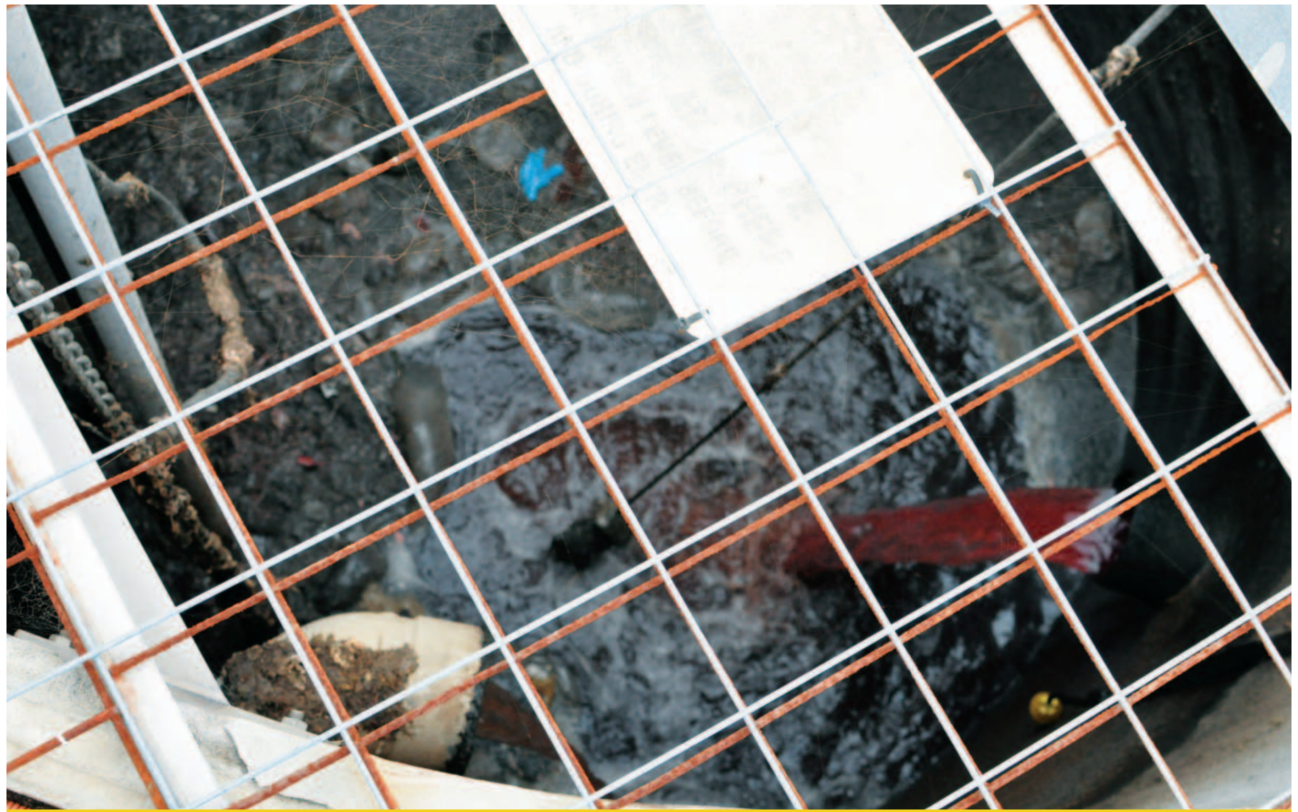


Figure 1. *One example of the arrangement of upstream technologies in meat processing plants*



Typical meat processing raw wastewater ©MINTRAC courtesy of Big River Pork

Reducing suspended solids

There are three main technologies used in Australian meat plants for reducing suspended solids levels. The forth technology listed below is less commonly used.

Static screen

This is a vertical screen, usually comprising a wedgewire screen to minimise blinding (blockage of the apertures by fine solids or fats), which has no moving parts. The raw waste water is pumped into a weir above the screen which seeks to provide an even overflow of waste water down the screen. Normally a concave or 'bow' shape is used. Most of the liquid passes through the top of the concave screen. The lower, flatter part of the screen is used to drain more liquid from the solids before they are discharged from the screen. A more recent innovation is a Baleen screen, where the screen is a fine, flat screen that slopes slightly. This type of screen uses mechanical water spray arms to move the solids towards the discharge.

Rotary screen

This is a rotating horizontal cylindrical screen. The incoming waste water is placed either inside the rotating cylinder, or less commonly, on the outside top of the screen. A helical internal guide moves the solids to the opposite end of the rotating cylinder, where it discharges.

Screw Press

A screw press comprises a rotating screw in a compression barrel, fitted at the inlet end, with a slotted screen for initial dewatering. This device depends on the compressed solids forming a 'plug' at the discharge end, against which the incoming solids are compressed by the action of the screw and dewatered. This device does a magnificent job of dewatering fibrous solids, such as manure and especially paunch, since they form an excellent plug. The discharged solids can be quite dry to touch.

Degritting Hydrocyclone

Hydrocyclones are commonly used for separating dense solids (sands, grit) from water. Waste water is pumped into the conical hydrocyclone tangentially, creating a swirling motion in the unit. The denser particles are 'flung' to the inner wall and slide down to the bottom discharge. The water and finer or lighter solids remain centred in the unit and are discharged near the top. This type of hydrocyclone is widely applied in the mining industry for separating dense solids and has proven effective for removing grit and sand from stockyard waste water.

Table 1 provides an overview of each of the technologies in the context of treating meat processing waste water.

Rotary screen ©Teys Australia (Wagga Wagga)

Table 1. Features of the most common upstream technologies used in meat processing plants for reducing solids concentrations

ISSUE	STATIC SCREEN	ROTARY SCREEN	SCREW PRESS	DEGRITTING HYDROCYCLONE
Capital cost	Low ($15 - $20K)	Low ($15 - $20K)	Moderate ($50 - $80K)	Moderate ($50 - $80K)
Life expectancy	Long life	Long life	Component replacement(s) after 10 years. Screens are subject to wear and may require replacement after 2-3 years.	Moderate life
Operating cost	Low	Low	Moderate	Low
Best for removing	Gross and paunch solids	All solids	Paunch and manure solids	Stockyard grit
Nature of solid discharge	Wet	Wet	Dry (up to 30% TS)	Wet
Effect of fat on operation of equipment	Blinds screen	Blinds screen	Little effect where sufficient paunch solid is present	Severe blockages
Weaknesses	Susceptible to hydraulic overloading and weir blockage	Susceptible to hydraulic overloading	Susceptible to damage from boluses or a lack of fibrous solids; damage from metallic objects in waste stream	Susceptible to blockages from paunch balls

Reducing oil and grease

There are several technologies commonly used in Australian meat plants for reducing oil and grease concentrations.

Saveall

The saveall is simply a large settling tank in which the raw waste water enters, usually after screening. The purpose is to provide sufficient time in a quiescent environment (i.e. still environment with no stirring, no aeration, no inlet jets) to allow fats to separate from the water and float to the top and for heavier solids to sink to the tank base. The separation is slow and typically requires a minimum 30 minutes retention time. Surface scrapers operate to gently tease the floating fat off the liquid surface up an inclined beach for drainage and then into a skip or screw for reprocessing. Some savealls are also fitted with base scrapers to remove solids in a similar manner.

Undosed Dissolved Air Flotation unit (DAF)

An Undosed DAFs is a common sight in Australian meat plants, especially where there is further waste water treatment. The DAF involves injecting a high pressure (approximately 400 kPa) stream of liquid, containing high levels of dissolved air (usually treated DAF effluent recycled via a pressurised saturator) into the raw waste water stream. When the pressure is released in the DAF tank, the dissolved air forms a mass of very fine air bubbles. These bubbles attach to particles and fat globules and lift them to the surface, where they form a float of aerated material. The floating material is scraped off for disposal or reprocessing and the clean water underneath is discharged.

Chemically dosed Dissolved Air Flotation unit (DAF)

This is a variant of the DAF process. It is more commonly applied in meat plants where the waste water is discharged to a municipal sewer. The process is exactly the same except that chemical coagulants and polymer are mixed into the waste water feed, increasing the removal of oil and grease, suspended solids and Chemical Oxygen Demand (COD). However the use of chamicals greatly increases the cost of this type of DAF compared with an undosed DAF. Additionally, this type of DAF generates large quantities of DAF float or sludge requiring disposal.

DAF ©MINTRAC courtesy of Big River Pork

Effluent exiting over DAF weir ©MINTRAC courtesy of Big River Pork

Deoiling hydrocyclone

This is a variant of the degritting hydrocyclone where the less dense oil and grease phase exits at the top of the unit and the heavier water phase flows out the base. This hydrocyclone requires very effective screening of the feed waste water to minimise blockages and are generally most effective on non-render red streams.

Table 2 presents information for these technologies as applied to meat processing effluent.

Table 2. Common upstream technologies used in meat processing plants for reducing oil and grease concentrations

ISSUE	SAVEALL	UNDOSED DAF	DOSED DAF	DEOILING HYDROCYCLONE
Capital cost	Low	High	High	Moderate
Operating cost	Low	Low	High	Low
Best for	Non-render plants	Fat reduction when biological treatment follows	Sewer discharge where space is tight	Fat recovery from red streams
Nature of solid discharge	Sloppy and wet	Sloppy and wet	Firmer and wet	Sloppy
Weakness	Hydraulic overloading and high temperatures	Hydraulic and/or solids overloading emulsified fats (LTR systems)	High chemical cost and large sludge production	Blockages from paunch balls

Reducing flow variation

A major challenge for most meat plants is the wide variation in waste water flow during a 24 hour day. Typically, the largest flow occurs during the processing shifts when water consumption is at its maximum and all the ancillary processes, such as rendering, stockyard sprays, gut room activities and boning, are operating. During the first few hours of cleaning flows tend to reduce to about 60 – 80% of process flows, before falling away to almost nothing once cleaning is completed.

For most meat plants with downstream anaerobic ponds, there is little need for balancing or 'equalising' the waste water flow, since the anaerobic pond acts as a very large balancing pond. In these cases, the saveall or a waste water pump pit is the only form of flow balancing.

Where waste water is discharged to sewer via a chemically dosed DAF, more care is needed to provide a more consistent flow to the DAF. For these plants, a large balancing tank is provided to accommodate the peak flows and discharge the waste water to the DAF at a more constant rate. The main challenges for balancing tanks are:

- minimising odours
- ensuring mixing to minimise solids settling
- minimising corrosion especially if the tank is inside a building structure.

Legislative and regulatory requirements

Direct regulatory requirements concerning upstream treatment will be stated in the facility's environmental protection licence, permit or approval issued by the State Government. It is generally rare for upstream treatment to be mentioned.

There are significant health and safety concerns with upstream processes, mainly related to the risk of confined spaces – pits, savealls etc. Raw waste water which remains stagnant for long periods may generate potentially toxic levels of Hydrogen sulfide (H_2S) due to protein decomposition. Extreme caution must be exercised in entering such places (refer to confined space regulations).

Commissioning upstream processes

Most upstream treatment technology is proprietary turnkey equipment with very short liquid retention times (typically less than 40 minutes). Consequently commissioning this type of equipment is generally associated with:

- ensuring proper orientation and operation of mechanical and electrical components
- ensuring correct programming of PLC gear
- confirming sludge volumes and removal frequency.

The performance will generally be clear within an hour from startup. The one exception is a chemically dosed DAF, where considerable experimentation may be required to find the optimal dosing level and chemicals.

Operating and maintaining upstream systems

Operator responsibilities

Upstream treatment systems usually require the bulk of the operator's time due to:

- the need for regular removal and disposal of solids discharges from the various processes
- the need to continuously ensure blockages and other issues related to the variability in the various raw waste water streams entering the treatment system are dealt with
- cleaning of plant to minimise vermin and blockages.

Recommended day-to-day operator responsibilities are described in Table 3.

Table 3. Operator responsibilities for upstream processes.

UPSTREAM PROCESS	IMPORTANT OPERATOR RESPONSIBILITIES
Screen	• Ensure inlet weirs are not partially blocked by gross solids (intestines, gloves, etc.). • Ensure regular cleaning of screens to minimise fat accumulation which causes wet discharge solids. • Control solid discharge disposal.
Screw press	• Ensure solids discharge is not too wet (adjust pressure plate). • Any pre-screen for bulk solids is kept clear. • Control solid discharge disposal.
Hydrocyclone	• Check regularly for blockages of the inlet and outlet apertures. • Control solids discharge disposal.
Saveall	• Ensure inlet weirs are not partially blocked by gross solids (intestines, gloves, etc) and flow into saveall over the inlet weir is even. • Ensure scraper sets are running correctly (not too fast to cause water disturbance; not too slow so float builds too thick). • Control solid discharge disposal. • Check at least weekly for solids buildup in the saveall if bottom scrapers are not fitted. • Servicing and rotation of pumps or ensuring servicing has been done.
Undosed DAF	• Ensure inlet weirs are not partially blocked by gross solids (intestines, gloves, etc.) and flow into DAF over the inlet weir is even. • Check that DAF aeration is running correctly, e.g. air volume to the saturator, saturator pressures. When the float is pushed away, the emerging float should look like a fine milky froth. There should be no big air bubbles (larger than 1 mm diameter) erupting on the surface. • Ensure scraper sets are running correctly (not too fast to cause water disturbance; not too slow so float builds too thick). • Control solid discharge disposal. • Check for solids formation in cold weather. • Check at least weekly for solids buildup in the DAF if bottom scrapers are not fitted.
Dosed DAF	• As for DAFs above. • Monitor coagulant and polymer inventory and dosing.

Solid discharge control

All upstream processes generate solids discharges that are typically wet, sloppy, usually fatty and unpleasant to handle. For large meat plants, there will be a very significant volume produced (quite often 100 wet tonne/week or more). While some of these solids may be returned for processing, others need disposal. This is a major part of day-to-day operation.

It is important that the solids are handled carefully since spills often return the material to the waste water treatment system and/or sewer which is undesirable.

Inspection

The upstream treatment process will need to be inspected several times a day to ensure everything is operating properly and to watch out for overflows caused by plant incidents, blockages or equipment failures (pumps, etc). The difficult nature of the raw waste water means that these incidents can be common and overflows off-site can bring about significant environmental damage, public nuisance (due to vermin attracted to the effluent, offensive odour and coating infrastructure in unpleasant material, such as fat, blood or manure) or fines from EPAs.

Table 3 outlines the most important responsibilities. Other more general ones include:

- checking that monitoring equipment is functioning (flowmeters, etc)
- notifying maintenance when breakdowns or malfunctions occur
- notifying management where excessive quantities of fat, blood or manure are observed entering the waste water system. This represents a significant loss of product and they may be completely unaware of the problem.

Monitoring

The degree to which upstream processes need waste water quality monitoring depends on the unique features of the facility. Twice a year you should collect a sample of the waste water exiting the upstream process for analysis in an external laboratory. Such measurements need to be informed by people with experience in sampling of highly variable waste water streams.

Where chemical dosing of the DAF plant occurs, quality monitoring will be more important and regular, especially if the DAF-treated waste water is discharged to sewer. This sampling and testing will typically occur daily (at least). The operator may conduct some testing on-site to help control the process.

Shutdowns

Some facilities have shutdowns of production for a month or so. This does not affect upstream processes and indeed provide a welcome period for cleaning and maintenance. Most upstream treatment processes will function properly within 30 minutes or less of restart.

Supervisor/management responsibilities

The proper operation of upstream processes is essential to the robust and reliable performance of the entire waste water treatment plant and compliance with environmental conditions in the facility's licence. Unfortunately upstream treatment areas are rarely pleasant to work in, especially for maintenance personnel, and they can easily become neglected and rundown.

The problem with waste water treatment systems are that they are like dominos. If the upstream treatment begins to malfunction, downstream treatment processes such as Covered Anaerobic Lagoons (CALs), activated sludge systems or ponds will generally fail sooner than they otherwise would. It can be prohibitively expensive to fix.

The main responsibilities for management are as follows.

- Ensure that appropriate investment and maintenance support is provided to the upstream treatment area.
- Monitor the upstream treatment area for evidence of large amounts of blood or tallow. This may indicate that valuable product is being lost down the drain.
- Oversee proper disposal of waste solids from the upstream process area. Off-site disposal of these wastes is increasingly difficult and expensive.
- Conduct regular (approximately six monthly) representative sampling of the waste water that has been treated by the upstream treatment system. This provides a valuable benchmark of waste water strength and is useful when upgrading downstream processes.
- Regularly monitor the discharge to sewer to ensure Council charges are accurate and to assess the benefit of improved treatment. Where the waste water is discharged to sewer following upstream treatment, there is usually substantial financial benefit in such monitoring.

Available training programs

IWES, owned by the University of Queensland, offers a five day course run annually on the Gold Coast and Sydney entitled 'Principles of waste water treatment'.

Water Training Australia offers a number of courses that relate to waste water operations and can be undertaken as individual units or as a package to suit your needs. Some of these units include:

- NWP207A Work effectively in the water industry
- NWP208A Perform basic wastewater tests
- NWP218B Perform sampling
- NWP221A Operate basic flow control and regulatory devices in water or waste water treatment network systems
- NWP262A Monitor and report wastewater treatment processes
- NWP346B Monitor, operate and control wastewater treatment processes
- NWP352B Monitor, operate and control dissolved air flotation processes

ANAEROBIC PONDS

Overview of anaerobic ponds

How they work

Anaerobic ponds play an important role in the treatment of meat processing waste water. Their key function is to reduce the level of organic contaminants such as Biological Oxygen Demand over five days (BOD5), COD and to a lesser extent oil and grease. They have little effect on nitrogen and phosphorus (nutrients) and pathogen numbers.

Anaerobic ponds contain a complex mix of bacteria that complete a two step process. The first step converts the incoming organic load (e.g. proteins from blood, oil and grease from tallow) into smaller organic molecules (acetic acid, ethanol, etc.). The second step converts the smaller organic molecules into biogases (methane (CH_4), hydrogen (H_2) and carbon dioxide (CO_2). The biogas exits the waste water and so the BOD5 and COD of the water are reduced.

There are three important things to know about anaerobic ponds.

1. Anaerobic ponds work entirely in the absence of oxygen. Oxygen is toxic to the bacteria that generate most of the gas, a group called the methanogens. That we do not need to add oxygen to the ponds makes them very cost effective to operate. However, without oxygen, these ponds produce a number of unpleasant smelling by-products including:

- ammonia (NH3)
- hydrogen sulphide (H2S) – a rotten egg smell and toxic gas
- a variety of amine and volatile acid compounds which smell like rotting fish, sweet cabbage or vomit.

Consequently, offensive odours can be a problem with anaerobic ponds. No supplement can be added to prevent this without killing the pond.

2. Anaerobic ponds generate much less sludge per tonne of incoming organic load than aerobic treatment systems. Consequently there is a lot less difficult biological solid to deal with at the end of the process (see the calculation below). Despite this, anaerobic ponds may fill with solids rapidly if primary treatment is poor.

3. Anaerobic ponds generate large quantities of methane, which is an energy-rich fuel. For comparison, coal seam gas is largely methane. Methane is very detrimental in climate change. It is 21 times worse at warming the atmosphere than an equal amount of CO_2. However, if we capture it, it can be used for boiler fuel or for making electricity in gas engines. As such, the Australian meat processing industry is increasingly installing Covered Anaerobic Lagoons (CAL), in which a plastic cover is stretched over the pond to capture the biogas for use. Doing this makes little difference to the treatment performance of the pond, but it reduces the impact on global warming and odour emissions from the anaerobic pond.

Finally, if the anaerobic pond fails for any reason, the performance of the entire downstream pond system will collapse and produce non-compliant final waste water.

Table 4 contrasts the positive and negatives of anaerobic ponds.

Table 4. Benefits and challenges of anaerobic ponds.

POSITIVES	NEGATIVES
High removal of organic load	Offensive odours are produced
Tolerant to high Total Suspended Solids (TSS) and oil and grease levels	Effluent needs further treatment
Cheap to build relative to other technologies	Significant contribution to facility Scope 1 emissions if methane is not captured and burnt
No energy input required	
Produces energy-rich methane	
Produces less sludge than other technologies	
Needs little operational input	

Two types of anaerobic pond

1. Naturally Crusted Ponds

The traditional anaerobic pond operating in the meat processing industry is a deep (usually at least 3 metres deep) basin which forms a floating crust over time consisting of a mixture of paunch material and tallow. The crust may become covered in grass, reeds and other plant life.

This natural crust is considered to play a positive role for the pond in that it:

- insulates the pond contents and helps maintain the pond at high temperatures during cold winter months
- helps minimise odour emissions off the pond, and
- minimises oxygen entry into the pond through the water surface.

The crust does not need to be thick to achieve these benefits. If the crust is too thick it reduces available treatment volumes.

Natural crusted pond ©Teys Australia (Wagga Wagga)

2. Covered Anaerobic Lagoons (CAL)

In the last decade, anaerobic ponds have been designed with plastic floating covers which seal the pond from the atmosphere and allows capture of the biogas. For CALs, a naturally occurring crust is a problem since it may damage the plastic cover.

The CAL works biologically in an identical manner to naturally crusted ponds. There is little difference in treatment performance. The main advantages of CALs are that:

- biogas is captured either for flaring (to reduce carbon emissions by destroying the methane), or for other uses such as cogeneration or boiler fuel
- odour emissions are better controlled.

The downside of CALs is their greater cost (usually about double that of naturally crusted ponds).

Natural crusted pond ©Teys Australia (Wagga Wagga)

Calculation of sludge production

Your meat plant generates 1.5 mega litres per day (ML/day) of raw waste water with a COD concentration of 6,000 milligrams per litre (mg/L). How much biological sludge would you generate per day using:

a) an anaerobic pond?

b) an aerated pond?

Assume 75% COD removal across both systems.

<u>Answer:</u>

Typical sludge generation for these two systems is:

Anaerobic ponds:	0.05 – 0.1 kg sludge/kg COD removed
Aerated ponds:	0.5 – 0.6 kg sludge/kg COD removed

Anaerobic pond sludge production:

COD removed by treatment = 1.5 [ML/day] x 6,000 [mg/l] x 75/100 [% COD removal]

= 6,750 kg COD removed/day

Dry sludge produced (kg TSS/day) = 6,750 [kg COD/day] x 0.1 [kg sludge/kg COD removed]

= 675 kg/day

This is dry sludge. So assuming it settles out on the base of the pond at 5% total solids:

Wet sludge produced (kg/day) = 675 [kg dry sludge] / (5/100) [% TS]

= 13,500 kg/day. Ouch!

If this sludge has a density similar to water at 1,000 kg wet sludge/m^3:

Wet sludge volume (m^3/day) = 13,500/1,000

= 13.5 m^3/day of wet black stuff every production day!

How much a year? If 240 processing days/year:

Wet sludge (m^3/year) = 13.5 x 240 = 3,240 m^3/year.

Aerated pond sludge production:

The anaerobic pond sounds bad at 3,240 m^3 of wet, gooey black sludge annually. Let's look at replacing it with an aerated pond:

COD removed by treatment = 6,750 kg COD removed/day – same as anaerobic pond.

Dry sludge produced (kg TSS/day) = 6,750 [kg COD/day] x 0.5 [kg sludge/kg COD removed]

= 3,375 kg/day

This is dry sludge. Making the same assumption as the anaerobic pond that it settles out in the pond at 5% total solids:

Wet sludge produced (kg/day) = 67,500 kg/day. Wow.....

If this sludge has a density similar to water at approximately 1,000 kg wet sludge/m^3:

Wet sludge volume (m^3/day) = 67.5 m^3/day of wet black stuff every production day!

How much a year? If 240 processing days/year:

Wet sludge (m^3/year) = 67.5 x 240 = 16,200 m^3/year.

Comparing the sludge production for the two pond systems:

Anaerobic pond:	3,240 m^3/year
Aerated pond:	16,200 m^3/year

Note that we have taken a relatively low sludge production figure for aerated ponds and a high one for anaerobic ponds. This is why we prefer anaerobic ponds.

Legislative and regulatory requirements

Direct regulatory requirements concerning anaerobic ponds will be stated in the facility's environmental protection licence, permit or approval, which is issued by State Government. Probably the most common requirement is for the pond to have a certain freeboard to prevent overflows.

Methane emissions from anaerobic ponds have become an important issue for meat processing plants captured by the various CO2-e thresholds under Commonwealth carbon emission regulations. The most common of these has been the requirement to report emissions from anaerobic ponds under the National Greenhouse and Energy Reporting System (NGERS). Most meat processing companies do this using default values based on production throughput and Method 1.

For CALs an additional layer of regulatory impact arises from the capture and use of the biogas. This involves compliance issues relating to various State-based agencies concerned with safety and gas fuels.

Finally, there are significant health and safety concerns with anaerobic ponds, whether naturally covered or as CALs. These concerns relate to the potentially toxic (especially H_2S), flammable (methane), or suffocating nature of the biogas. This is important where there are inlet and outlet pits and other confined space areas where such gases can build up to dangerous levels.

Signage relating to the deep nature of the ponds and the risks posed by the biogas must be displayed. In Queensland, and it is expected that other states are similar, a gas producing CAL will require licensing by the relevant state gas regulatory office that controls natural gas production.

Establishing anaerobic ponds

General comments

Commissioning of new or retrofit anaerobic ponds is a task best guided by experienced and suitably qualified suppliers. The critical aspect of commissioning a new anaerobic pond is to ensure the growth of the complex mix of bacteria needed for the pond to function. This is challenging for the following reasons.

- Methanogenic bacteria (which generate methane) are very slow growing, especially in colder climates and typically require three to four months to reach optimal operating levels.
- Faster growing acidogenic bacteria, which break down complex molecules (proteins, oils and fats) to simpler ones (acetic acid, hydrogen gas) may outcompete methanogens and create an environment in the pond where methanogens become ill and fail to grow. Under these conditions, the new pond fails to achieve good COD removal.

Fortunately, experience has shown that meat processing effluent is highly suitable for starting up anaerobic ponds with minimal difficulty. Most anaerobic ponds reach a reasonable degree of COD or BOD_5 reduction within a couple of months, but in systems operating at sub-optimal temperatures, it may require much longer.

Important factors for start-up

Important factors for successful start up are:

- avoiding organic shock loads from events such as blood or tallow spills reaching the pond
- extra monitoring of anaerobic pond effluent during start-up to provide good feedback to the pond designer or constructor so they can advise on progress
- attempting to increase pond temperatures as quickly as possible to get into the optimal range for operation (usually 28 – 35°C), however sometimes, a plant cannot operate at such temperatures
- ensuring as much paunch and intestine effluent as possible is fed to the pond (preferably minus the suspended solids) since these streams contain many of the bacteria needed for successful operation.

There are three clear signs that the anaerobic pond is well established and capable of processing the design organic load and flow.

1. There is substantial biogas production with good methane content.
2. COD or BOD removal is within 10% of design removal and stable from week to week. The design removal will vary from pond to pond due to unique aspects of each facility, but typical design COD removals are in the range of 70 – 90% of incoming COD concentration.
3. The Volatile fatty acid (VFA) to Total Alkalinity (TA) ratio is 0.25 or less.

Establishing a crust

If you are establishing a new non-CAL anaerobic pond within 1 km of neighbours, it is important to establish a natural floating crust as soon as possible. There are a number of ways of accelerating crust formation and some large ponds have been covered within two to three days. Factors which help this include:

- turning off or bypass savealls and dissolved air flotation plants for a few days
- floating straw out across the pond
- in windy regions, adding ropes across the surface of the pond (usually with floats) to help stop the wind pushing the crust around and breaking it up.

Operating and maintaining anaerobic ponds

Recommended daily operator responsibilities

1. Inspection

On a regular basis (preferably at least weekly) the following aspects of each anaerobic pond should be checked:

- Inlet – check for blockages and clear
- Outlet – check for blockages and clear.

For naturally crusted ponds you also need to check the following.

- Pond crust – check to see that the crust has not disappeared on any part of the pond, or has not changed. A good method is to take a photo of the crust from a given point using your mobile phone camera once a month and check the latest image against older ones. If the crust is disappearing, odour emissions may become an issue with neighbours.
- Pond walls – many anaerobic ponds are deep, with two to four metres of wall built up as earthworks. Walls can be damaged by:
- tree or shrub roots – emerging trees or shrubs should be killed immediately
- rain erosion – where severe erosion is observed, it may pay to apply protective biodegradable matting which allows grass growth for uncovered ponds
- burrowing animals such as wombats, rabbits, reptiles, etc. Eviction is recommended.

For covered anaerobic lagoons (CAL) you need to check the following conditions regularly as part of the regular inspection.

- Over-inflation of the cover – this exposes the cover to mechanical stresses from wind which may damage it. Most covers are designed to remain relatively flat on the pond surface. If over-inflation occurs, it is important to ensure the emergency release valves are not blocked (e.g. by slushy crust beneath the cover). These are installed to prevent damage to the pond cover in the case of over inflation.
- Leaks from the cover, for example due to animal damage.
- Build-up of crust under the cover – this can be observed through inspection ports and/or felt under the cover.
- Excess stormwater on the cover – if noted, then check the operation of the stormwater removal pumps.

Stormwater removal system off CAL cover ©MINTRAC courtesy of Camilleri Stockfeed Pty Ltd

2. Crust and vegetation

Vegetation around the inner walls of a pond will need regular control. Some vegetation helps limit erosion of pond walls, but excessive amounts can hinder access, making inspections or sampling difficult and hazardous due to snakes and other vermin (including wild pigs in Northern Queensland). In the case of CALs, a perimeter around the pond needs to be free of vegetation to prevent fires from reaching the large biogas store under the CAL cover.

Pond crusts can grow an amazing variety of plant life including trees, reeds and grass. Trees and shrubs need to be removed. Reeds and grass should be acceptable in deep ponds.

Always resist the temptation to burn vegetation off anaerobic ponds. If the biogas under the CAL cover catch alight it can take days to extinguish the fire.

3. Monitoring

Anaerobic ponds are typically large relative to daily flows and outlet composition will change only slowly. It is difficult to monitor inlet composition and generally isn't worthwhile except for particular reasons, such as replacement of the pond or for troubleshooting.

Outlet sampling and testing on a regular basis is recommended. Where intensive treatment systems follow the anaerobic pond downstream (e.g. activated sludge systems or discharge to sewer), sampling may be wise as often as weekly. Where the anaerobic pond has facultative ponds downstream and/or waste water is disposed to land, the frequency may be relaxed to once each month or quarterly.

The most critical parameters for monitoring of the outlet include:

- on-site – measure temperature, pH and electrical conductivity (EC) using a small, inexpensive portable instrument
- off-site – take a large sample of anaerobic pond effluent (5 litres minimum) and get it tested for COD as a minimum and preferably Volatile Fatty Acids (VFA) (mg/l as acetic acid) and terephthalic acid (TA) (mg/l as $CaCO_3$). Other parameters that may be useful include TSS, total kjeldahl nitrogen (TKN), ammonia-N and oil and grease.

Table 5 suggests optimal and sub-optimal ranges for these parameters. These numbers are a guide only.

Table 5. Recommended operating ranges for anaerobic ponds.

PARAMETER	PREFERRED RANGE	YOU'RE IN TROUBLE
Temperature	20 – 37°C	> 40°C < 10°C
pH	6.7 – 8.0	< 6.5
EC	< 3,000 µS/cm	> 10,000 µS/cm
COD	70 – 90% removal	< 50% COD removal A rise in outlet COD of more than about 30% on two consecutive occasions.
VFA/TA ratio	≤ 0.25	> 0.5

4. Diagnostics

The operator needs to be watchful for dysfunctional activity in anaerobic ponds.

Uncovered anaerobic ponds:

- Crust foaming – under certain conditions, the crust of anaerobic ponds develops a foaming crust that often starts in one area and expands quickly (e.g. over a few days). The foam can flow over the pond walls and off-site under extreme conditions. If you observe a foaming crust immediately call for specialist assistance.
- Gas Geysers – some anaerobic ponds can form volcano-type geysers on their crust, often near the inlet end. These bubble constantly as gas escapes the pond through them. A small number of such geysers is not a bad thing. If they spread across more than about a fifth of the pond surface, it may indicate the pond is overloaded. Seek help, or if you have ponds in parallel, divert some flow to the other pond(s).
- Excessive solids in the outlet discharge – this may be due to sludge build-up in the pond. Seek assistance.

Covered anaerobic ponds.

- CALs are also vulnerable to the foaming and excess solids in the effluent described above. However, where biogas flow measurement is installed, additional and valuable monitoring information is available:
- Slowing of biogas production – biogas production is the result of healthy anaerobic digestion. When gas production slows, or even worse stops, the anaerobic bacteria are either under extreme stress or have partially died off. Seek help immediately as continued operation may cause more damage to the delicate bacterial population.

5. Supplements

It is common for companies to promote biological products to make your anaerobic pond go better. It is rare for these to significantly improve a well designed and operated anaerobic pond.

Products that remove the crust off naturally-crusted anaerobic ponds are very risky. In these ponds, the crust is important for minimising odour release and keeping heat in the pond, especially during winter. Remove it at your own peril. Note that it is not scientifically possible for an anaerobic pond to operate without some offensive odour unless it is very underloaded (e.g. way too big for the incoming load) no matter how clever the supplement.

6. Shutdowns

Some facilities have shutdowns of production for a month or so. This will not seriously affect an established anaerobic pond's performance on start-up. Shutdowns of two to three months or more may require a more careful start-up.

Supervisor/Management responsibilities

- Review the monitoring data to observe trends with time. Due to their large volume, problems with anaerobic ponds emerge gradually over months. The best means of catching problems before they cause non-compliance with final effluent is to watch trends for COD removal, pH, temperature and VFA/TA ratio with time.
- Anticipate impacts of sustained increases or decreases in production on the operation of anaerobic ponds. Where needed, obtain specialist advice on these impacts.
- Promote maintenance expenditure as required.

Available training programs

IWES, owned by the University of Queensland, offers a five day course run annually on the Gold Coast and Sydney entitled 'Principles of waste water treatment'.

Water Training Australia offers a number of courses that relate to waste water operations and can be undertaken as individual units or as a package to suit your needs. Some of these units include:

- NWP207A Work effectively in the water industry
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- NWP352B Monitor, operate and control dissolved air flotation processes

AEROBIC PONDS

Overview of aerobic ponds

Aerobic ponds are typically shallow (less than 2 metres), large ponds which are commonly found downstream from anaerobic ponds. Their main purpose is to reduce BOD5 concentrations to levels suitable for irrigation to land without odour (typically BOD5, 100 mg/l) and to ensure that there is a reasonable level of dissolved oxygen (DO) in the treated water (DO more than 2mg/l).

Traditionally aerobic ponds come in one of three forms:

1. facultative ponds
2. aerated ponds
3. maturation ponds

Their main features are compared in Table 6.

Table 6. Characteristics of aerobic ponds.

PARAMETER	AERATED PONDS	FACULTATIVE PONDS	MATURATION POND
Usual depth (metres)	2 – 4	<3	<1.5
Aeration method	Mechanical	Top layer aeration/algae/wind	Algae/wind
Anaerobic layer?	No	Yes	No
Sludge production	High	Medium	Low
Risk of odour	Unusual	Possible	Unlikely

Facultative ponds

These are probably the most common aerobic pond in meat processing waste water treatment systems. Typically the first aerobic pond downstream of an anaerobic pond or CAL will always be facultative in behaviour.

The pond can be thought of as operating as two horizontal layers (see figure 2):

- a top aerobic layer, with good algal growth, positive dissolved oxygen levels and musty smelling
- a deeper anaerobic layer which performs exactly like an anaerobic pond.

In the top layer sunlight encourages the growth of green algae which photosynthesise during daylight and pump oxygen and alkali into the water to keep the top layer aerobic. At night this stops and an oxygen sag may occur (the top layer thins in depth as dissolved oxygen levels fall).

The bottom layer operates just like an anaerobic pond and does the bulk of the BOD removal. Reduced compounds rise into the aerobic top layer, where they are oxidised by aerobic bacteria to non-odorous compounds.

The only difference between a facultative pond and an anaerobic pond is the tonnes of BOD added per unit volume per day. Facultative ponds have a lower BOD added so that the oxygen can penetrate to a reasonable depth before being used for aerobic bacterial activity. As the mass of BOD added increases, the aerobic layer decreases in depth.

For example, if an abattoir doubles its throughput without increasing the volume of upstream anaerobic ponds, then the downstream facultative pond may become an anaerobic pond since there is extra BOD entering each day. In essence, the aerobic layer shrinks to nothing.

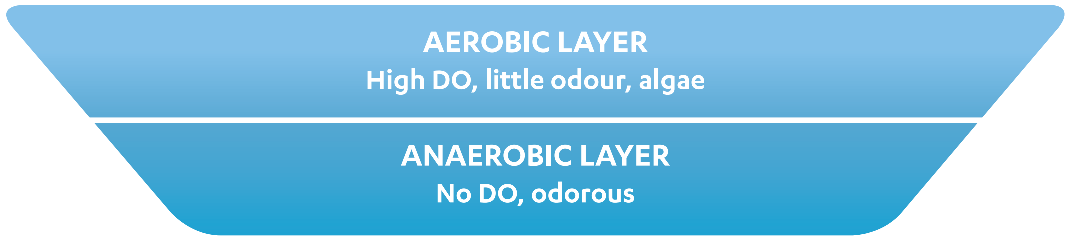

Figure 2. *Layering in a facultative pond. The interface between the layers moves up and down according to the amount of aeration of the top layer.*

The advantages and challenges of a facultative pond are compared in Table 7.

Table 7. Characteristics of facultative ponds.

POSITIVES	NEGATIVES
Good removal of organic load	Can smell bad when overloaded
Cheap to build relative to other technologies	Significant sludge forms over time
No energy input required	No significant nutrient or pathogen removal
Low odour when operated properly	May produce some methane
Can be converted to aerated pond if deep enough	
Needs little operational input	

Aerated ponds

Aerated ponds are increasingly common. They overcome the main limit of facultative ponds – which is the ability to add enough oxygen to keep an aerobic top layer. Rather than depending on algae to oxygenate the top layer, in aerated ponds oxygen is provided by:

- mechanical floating surface aerators
- submerged blower-aerated systems, such as air stones.

The aim is to provide either:

- enough air to ensure the top layer is kept aerobic – in practice this has proven very difficult to achieve since the time the air spends in the top layer is small
- enough air to aerate the entire volume of the pond (i.e. no anaerobic layer) – this is called a completely mixed pond and demands higher levels of power.

The main advantage of an aerated pond is that complete aeration of the contents can be assured simply by providing the appropriate aeration system. There is no dependence on less reliable natural or seasonal factors (algae, wind etc). Table 8 summarises the benefits and downsides of aerated ponds.

Table 8. Assessment of aerated ponds.

POSITIVES	NEGATIVES
Reliable removal of organic load	Significant bacterial sludge forms over time
Cheaper to build compared to activated sludge systems	No significant nutrient or pathogen removal
Low risk of odour when operated properly	More expensive to fit out with aeration and to operate than facultative pond
Needs little operational input	

Aerated pond ©Teys Australia (Wagga Wagga)

Maturation ponds

Maturation ponds are designed mainly to achieve disinfection (reduce pathogenic microorganisms) and reduce BOD to low levels. To do this effectively they have treatment systems upstream which reduce the incoming BOD load to very low levels. Their main feature is their shallow nature – less than 1.5 metres water depth. This is essential to allow sunlight and oxygen penetration to the base of the pond. Often they are green with algal growth, that provide a rich dissolved oxygen (DO) concentration and high pH (more than 7.5) in the water. This help kill pathogens.

For maximum effectiveness, two smaller ponds are superior to one large one. The benefits and problems with these ponds are described in Table 9.

Table 9. Properties of maturation ponds.

POSITIVES	NEGATIVES
Cheap to build and operate	Very limited capacity to remove BOD
Simple and robust	Limited capacity for upgrading due to the shallow nature
Low risk of odour when operated properly	Large land area needed for effective result
Achieves good degree of disinfection if total maturation retention time is 20 days or more	No ammonia or nutrient removal in winter
Can remove ammonia during summer months by physical volatilisation	
Needs little operational input	

Legislative and regulatory requirements

Direct regulatory requirements concerning aerobic ponds will be stated in the facility's environmental protection licence, permit or approval which is issued by State Government. Probably the most common requirement is for the pond to have a certain freeboard to prevent overflows.

Methane emissions from waste water systems have become an important issue for meat processing plants captured by the various carbon dioxide equivalent (CO_2e thresholds under Commonwealth carbon emission regulations. Well managed aerated and maturation ponds will have zero emissions. The only uncertainty would lie with facultative ponds. There is considerable lack of clarity relating to emission factors in the current NGERS Technical Guideline document for facultative systems. Most meat processing companies report using default values based on production throughput and Method 1, which eliminates the uncertainty.

Establishing aerobic ponds

General comments

Commissioning of aerated ponds is a task best guided by experienced and suitably qualified suppliers. For facultative and maturation ponds, the bacterial population should establish reasonably quickly, especially where there are properly operating anaerobic ponds upstream which will tend to seed the new pond.

Important factors for start-up: aerated ponds

For aerated ponds, the following are important factors for successful start-up.

- Avoid organic shock loads, from events such as blood or tallow spills, reaching the pond.
- Ensure the aeration system is operating properly.
- It can be useful to add sludge to accelerate start-up. This can often be obtained from a local sewage treatment plant. However, ensure a qualified expert checks the process first to make sure you are not importing problems.

Aerobic systems generally start up much faster than anaerobic systems due to the higher growth rates of aerobic bacteria. An aerated pond should achieve normal operating performance for BOD removal within two to four weeks.

The best signs that the aerated pond is well established and capable of processing the design organic load and flow are as follows.

- There is a good bacterial floc in the pond (this indicates growth).
- COD or BOD removal is within 10% of design removal and stable from week to week. The design removal will vary from pond to pond due to unique aspects of each facility, but typical design BOD removals are in the range of 50 – 70% of incoming BOD concentration.
- The DO level is more than 2mg/l.
- There is no unpleasant smell.

Important factors for start-up: facultative and maturation ponds

New facultative ponds may take several weeks to reach stable performance since they must establish an anaerobic population of bacteria in the bottom layer of the pond. If there is an established and well operating anaerobic pond upstream, this will assist. Sludge from an anaerobic or established facultative pond may be added to bring the pond up faster.

Maturation ponds will also take a few months to reach stable performance since they are typically large and there is little food to allow fast growth of the biological population. They are best left to establish themselves.

The only way to tell that a facultative pond is established is that it is achieving a suitable degree of BOD reduction. The pond designer can identify that value for you.

Operating and maintaining aerobic ponds

Operator responsibilities

The following day to day operator responsibilities are recommended.

1. Inspection

On a regular basis (preferably at least weekly) the following aspects of each aerobic pond should be checked.

- Inlet – check for blockages and clear.
- Outlet – check for blockages and clear.
- Aerated ponds – ensure the aerators are functioning properly.
- Pond foam (especially aerated ponds) – ensure that there is no crust or substantial foam on the pond. This is a bad sign for aerobic ponds.
- Pond crusts – aerobic ponds should not have crusts since they prevent good aeration of the water whether by mechanical aerators or algae and wind.
- Pond walls – aerobic pond walls can be damaged by:
  - tree or shrub roots (emerging trees or shrubs should be killed immediately)
  - rain erosion (where severe erosion is observed, it may pay to apply protective biodegradable matting which allows grass growth and protects from erosion)
  - burrowing animals such as wombats, rabbits, reptiles, etc. (eviction is recommended).

Mousse on aerated pond ©MINTRAC courtesy of Big River Pork

2. Vegetation

Vegetation around the inner walls of a pond needs regular control. Some vegetation helps limit erosion of pond walls, but excessive amounts can hinder access. This makes inspections or sampling difficult and hazardous due to snakes and other vermin (including wild pigs in Northern Queensland).

3. Monitoring

Aerobic ponds are typically large relative to daily flows and outlet composition will change only slowly. If an anaerobic pond is present upstream, the large variations in raw effluent composition are damped. Simple grab samples of the incoming anaerobic-treated and outgoing aerobic treated effluent are usually representative and reproducible.

Sampling and testing of the discharge of each pond on a regular basis is recommended. For aerated or facultative ponds where treated waste water is disposed to land, an appropriate sampling frequency is once each month or quarterly.

The most critical parameters for monitoring of the outlet include the following.

- On-site: measure temperature, pH and electrical conductivity (EC) using a small, inexpensive portable instrument.
- Off-site: take a large sample of the discharge from the pond (5 litres minimum) and get it tested for COD and TSS as a minimum. Other parameters that may be useful include total nitrogen, ammonia-N, total phosphorus and oil and grease.
- Where a pond is the final pond prior to effluent release, the facility environmental licence will typically list parameters that must be tested for compliance purposes and the frequency required.

When sampling aerobic ponds (facultative or maturation) it is important to collect the sample from the discharging outlet. Samples scooped from the surface of these ponds may not be representative of the discharge due to stratification effects where the top layer of the pond is different in composition to the deeper volume.

It is challenging to define typical operating parameters for these ponds because they vary extensively depending on location, climate and season. If you are unsure, seek expert advice.

4. Diagnostics

The operator needs to watch for various problems in aerobic ponds, including:

- Foaming (aerated ponds only) – for aerated ponds, there may be a short period (approximately 1 week) when substantial foam is seen on the surface of aerated ponds during start up. This should largely disappear once the pond is established. If there is any sign of a persistent white, pavlova-mix style mousse that often looks like fat, seek urgent appraisal by an expert. Foam is often noticed prior to a rain period when atmospheric pressure drops, this may indicate a pond operating close to its limit.
- Crusts (maturation ponds) – sometimes at the change of season (summer/autumn or winter/spring), a pond may suffer an inversion event. This is sudden and involves the bottom sludge suddenly rising (often overnight) and covering the pond. This is a natural event and generally the best means of repairing the damage is to use a travelling irrigator spray to sink the floating sludge. Seek expert help if required.
- Excessive solids in the ponds or outlet discharge – this may be due to sludge build up in the pond. This is a particularly common issue when the pond is immediately downstream of an anaerobic pond. You need a regular program for removing sludge build up in this pond. Seek assistance as required.
- Offensive odours – aerobic ponds may smell musty or lakey. This is normal. They should never smell offensive. If they do, it is usually a sign that either:
- the pond has become anaerobic, typically due to BOD overloading due to a malfunctioning anaerobic pond upstream, or a severe spill of blood or tallow in the previous month
- the pond has filled with sludge to within 30cm of the top of the surface. In this case, desludging is required.
- Blue green algae – under hot, still summer conditions in much of Australia, facultative or maturation ponds may stratify, with the top surface layer of water reaching very warm temperatures (more than 30°C). Under these conditions various blue green algae can bloom and grow. In the worst cases, these algae can release toxins which can cause problems to personnel and animals if the treated water is recycled back to stockyards, or the like. The best answer is to destratify the pond where possible (usually power is needed to do this).

5. Supplements

It is common for companies to promote biological products to make their aerobic pond go better. It is rare for these to significantly improve a well designed and operated pond, however if a pond is under stress, such supplements may help but usually at a significant cost.

6. Shutdowns

Some facilities have shutdowns of production for a month or so. This will not seriously affect an established aerobic pond's performance on plant start-up. Shutdowns of two to three months or more may require a more careful start-up. Aerated ponds are more vulnerable to shutdowns of even two weeks and expert advice may be useful to help a company manage the impact.

Supervisor/management responsibilities

- Review monitoring data to observe trends with time. Due to their large volume, problems with most aerobic ponds emerge gradually over months. The best means of catching problems before they cause non-compliance with final effluent is to watch trends for COD removal with time.
- Be aware that aerobic pond systems will collect sludge over time. While this can be managed by clever design, loss of performance gradually over time can indicate a sludge build up that needs addressing.
- To anticipate impacts of sustained increases or decreases in production on the operation of anaerobic ponds. Where needed, obtain specialist advice on these impacts.
- Promote maintenance expenditure as required.

Available training programs

IWES, owned by the University of Queensland, offers a five day course run annually on the Gold Coast and Sydney entitled 'Principles of waste water treatment'.

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BIOGAS CAPTURE SYSTEMS

Overview of biogas capture systems

Biogas properties

Biogas generated by CALs is mainly a mixture of methane (55 – 75% v/v) and carbon dioxide. Minor traces of other gases such as hydrogen sulphide (H_2S) and volatile organic compounds (VOC) are usually present and may give the biogas an unpleasant odour and corrosive properties. The biogas is typically saturated with water vapour due to the confined, humid and often warm nature of the CAL.

Table 10 outlines the main features of biogas, relevant to the role of plant operator. Methane has a bad reputation due to its role in coal mine incidents, but in reality it is one of the less dangerous fuels due to:

- a high ignition temperature (595°C) compared to other fuels (e.g. butane is 365°C)
- low density, which means it rises more rapidly in air than other gases which are heavier than air and may flow along the ground to an ignition source.

Table 10. Properties of biogas from CALs treating meat processing waste water

PROPERTY	GAS COMPONENT RESPONSIBLE	COMMENT
Flammability	methane	Methane burns in air between the composition limits of 5 – 15% by volume. Outside of this limit it is not flammable.
Ignition temperature	methane	595°C. Methane requires very hot temperature for ignition.
Dustiness	dust	Biogas contains negligible dust which might enhance its explosive properties.
Odour	hydrogen sulphide, VOCs	Biogas from meat plants is usually contaminated with H_2S making it offensive in odour (rotten eggs). Note methane is odourless.
Density	methane	Lighter than air. Biogas dissipates rapidly.
Toxicity	hydrogen sulphide, carbon dioxide	H_2S is toxic above 350 ppm and lethal at levels of 800 – 1,000 ppm. This level of H_2S is common in meat processing biogas. CO_2 causes suffocation.
Global warming potential (GWP)	methane	Methane has a GWP of 21 times CO_2. Biogas methane is a major contributor to a facility's Scope 1 emissions.

Despite having numerous uncovered anaerobic ponds operating for many years, reports of methane fires are rare. There is negligible oxygen under the CAL cover due to its exclusion from the pond and its rapid consumption by bacteria if it enters in the pond waste water feed. An explosive or combustible mixture of methane and air requires methane to be in the range 5 – 15 %v/v with air. Outside of this range, the gas will not burn.

It is physically impossible to get enough air under the CAL cover to create a combustible mixture unless it is forced fed. Nevertheless, any leak of biogas from the CAL, or the biogas system (where it is more pressurised) must be treated with caution to avoid ignition in the immediate vicinity of the leak, since in these circumstances there is abundant oxygen.

Typical biogas capture system

A standard layout showing the main components for the biogas capture system for a CAL is presented in Figure 3. The main components include the following.

- Biogas pipeline – this conveys biogas from the CAL cover to the flare. It may be buried, or above ground.
- Knockout pot – this is generally a stainless steel vessel situated at the lowest point of the biogas pipeline to collect water condensing from the water-saturated biogas as it cools. The water can be safely drained at this point. This protects the downstream blower and instruments from damage.
- Flow control valve – a PLC system typically controls biogas flow to the flare through the automated flow control valve. In many cases, the valve is controlled according to the pressure under the CAL cover permitting the flare to operate at a number of biogas flow settings.
- Gas Blower – the blower provides positive pressure to convey biogas to the flare for incineration.
- Slam shut valve – a fast acting valve system which shuts off the biogas supply in the event the flare is not functioning or losing flame.
- Flame arrestor – this safety device prevents a flame front running back through the biogas supply line.
- Flare – the flare is a device which incinerates the biogas safely. There are two main types of flare available.
    1. Fully enclosed. This flare type controls the air supply to the biogas burner to ensure a hot flame for maximum odour and methane destruction. The flare is completely enclosed in a refractory shield.
    2. Candlestick. This flare is a simple Bunsen-burner type flare consisting of a vertical biogas tube with burner on top. The air supply is unlimited. This type of flare may have a metal shroud around the burner to prevent wind extinguishing the flame (which otherwise requires constant re-priming of the flare). This flare is less sensitive to biogas supply, but usually generates a cooler flame associated with less complete odour and methane destruction.
- Priming System – a priming system usually consists of a LPG cylinder to feed the flare priming system in case of the need for flare reignition. The priming system is not shown in figure 3.

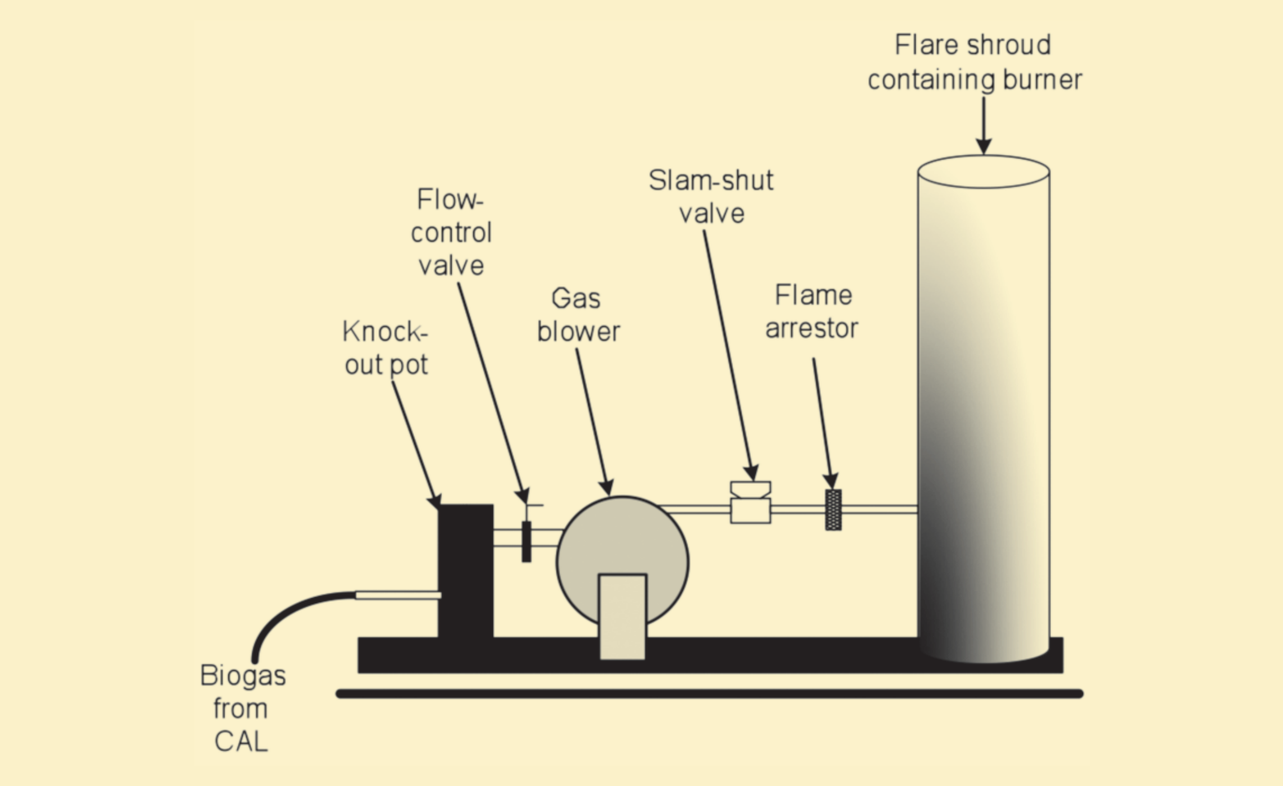

Figure 3. *Typical layout of a biogas delivery system and flare.*

Enclosed Biogas Flare for combustion of methane produced from anaerobic waste water treatment ©Teys Australia (Wagga Wagga)

Candlestick flare ©Mike Spence, Churchill Abattoir Management Pty Ltd

The biogas capture system has two roles.

1. It incinerates all biogas generated by the CAL to ensure the methane content of the biogas is converted by burning into carbon dioxide. Methane has a global warming potential of 21 times carbon dioxide. Consequently incinerating the biogas largely eliminates Scope 1 emissions from the CAL (especially since the carbon dioxide produced counts as a zero emission).
2. It ensures that simultaneously all gaseous compounds with an offensive odour (H_2S especially) are oxidised to odourless components.

Where the biogas is used for cogeneration in a biogas engine, or diverted for boiler fuel, the flare exists as a contingency element of the system only.

Legislative and regulatory requirements

The regulatory requirements for the biogas capture system has several parts:

- odour emission requirements
- gas equipment manufacture and operation requirements, including all components from the point of biogas exit from the CAL to the flare, including the pipeline
- climate change impacts.

Odour and other emission requirements

Direct regulatory requirements concerning odour emissions will be stated in the facility's environmental protection licence, permit or approval which is issued by State Government. The same document will also indicate whether there are other compliance issues with flare operation such as light or noise emissions.

Safety requirements

The safety of gas appliances is regulated by each State and Territory. There is diversity of regulations regarding biogas flares and capture systems between the States. In some cases biogas as a fuel is overseen by State regulatory offices (e.g. Victoria and Queensland), in others they are not. A reasonably recent summary of this is given in the Rural Industries Research and Development Corporation (RIRDC) publication Assessment of Australian Biogas Flaring Standards (2008).

There are stringent regulations concerning the manufacture and installation of flare components associated with the biogas capture system. The manufacturer will have manufactured and installed their apparatus to these standards.

Supervisors and operators should be aware of the potential risks associated with biogas and follow appropriately designed protocols to minimise hazards.

Carbon emission issues

As noted in Table 10, biogas contains high quantities of methane which has a global warming potential 21 times that of CO_2. Emissions associated with methane and N_2O from CALs and anaerobic ponds must be reported under the National Greenhouse and Energy Reporting Scheme (NGERS) Act 2007 for facilities or corporations which trigger the appropriate thresholds. Typically emissions from anaerobic treatment of the facility waste water can comprise over half or more of Scope 1 emissions, especially where the facility operates natural gas boilers.

A major advantage of CAL technology is that the captured biogas is flared, which reduces emissions by over 97%. The most recent copy of the NGERS Technical Guidelines issued by the Department of Climate Change outlines calculations for flared biogas.

Commissioning the biogas capture system

Commissioning of the biogas delivery system and flare is best guided by experienced and suitably qualified suppliers. The CAL feeding the biogas system needs to produce suitable quantities and quality (methane content) of biogas. Since it may be up to a month before suitable quantities of biogas are produced by a new CAL, commissioning of the biogas delivery system lags that of the CAL itself.

In addition, there needs to be sufficient biogas to maintain operation of the flare. Once this occurs, the low and high fire levels on the flare can be set, usually based on gas pressure under the cover.

Flare Ignition Sequence

This is usually performed automatically and is controlled through the electrical panel near the flare. To start the sequence, most systems rely on a switch or button operation. Pilot fuel is lit with a spark igniter after the pilot gas supply solenoid valve is opened. The flame safeguard system checks the existence of a pilot flame and automatically opens the block valve and the biogas blower starts. This begins supply of biogas from the CAL. This leads to ignition and operation of the main biogas flare which seeks to obtain a minimum flame temperature of about 760°C. If the flare fails to get to this minimum operating temperature within a set time, it shuts down and times out for a period.

Where conditions are very windy, you should fit the candlestick flares with a wind shroud to prevent the wind blowing the flame out. Otherwise, the flare will run through the pilot fuel at an expensive rate.

Operating and maintaining biogas capture systems

Operator responsibilities

1. Upon inspection of the system:

- Observe all posted safety signs and protocols. Become familiar with the location of safety equipment such as fire extinguishers, emergency shutdown points, etc.
- Ensure monitoring instruments, such as biogas flowmeter, methane and/or oxygen analyser and pressure detection devices are operating properly. The high moisture content and corrosiveness of the biogas can cause problems with instrumentation. Where instruments become unserviceable, seek maintenance support quickly.
- Inspect the biogas delivery lines, especially where they connect to the CAL and major equipment items and check for leaks regularly. Notify maintenance if found. Note that air leaks into the biogas piping is as much a concern as methane leaks out. Generally it is recommended that the oxygen content of biogas is less than 4% of the volume.
- Ensure that the flare and blower are operating satisfactorily. If the flare alarms out constantly on for long periods seek urgent assistance as biogas will rapidly accumulate under the CAL cover, causing it to inflate and begin emergency venting. In windy places, this can expose the CAL cover to high mechanical stresses with the risk of severe damage. Check at least weekly for unusual blower vibration or temperature and notify maintenance if there is.
- Drain the knockout pot, if a manual fitting is supplied, at least weekly and more often if necessary. Look for evidence of unusual drainage water, for example, water containing foam or mousse-like contents. This may indicate contamination of the biogas system with bacterial material.
- Check the pilot gas fuel is sufficient for flare operation regularly.
- Check on a regular basis (preferably daily) how the flare is operating. The flame should be colourless and odourless.

2. When monitoring the system:

Most monitoring is performed on-line and typically a biogas capture system should be fitted with:

- biogas flow meter
- methane and/or oxygen analyser
- CAL cover pressure transmitter
- various system temperature and pressures.

This information can be logged to the facility supervisory control and data acquisition (SCADA) system for reporting and monitoring.

A log should be maintained by the operator of any unusual aspects of the system. This can be related to issues such as CAL cover inflation, etc.

Supervisor/management responsibilities

The primary responsibilities of the supervisor should be to ensure that...

All safety protocols associated with the CAL and biogas capture system are clearly laid out in work instructions and standard operating procedures.

The operator is competent in following them.

Necessary personal protection and other safety equipment is available.

The biogas capture system involves several significant hazards with risks of high temperatures (flare), suffocation or poisoning (from biogas components), fire (methane) and usually remoteness from the facility if something goes wrong and help is needed.

Other main responsibilities for management are as follows.

- Ensure that appropriate investment and maintenance support is provided to the biogas capture system. As stated above, in the event of biogas system failure, biogas will accumulate rapidly under the CAL cover with risks of mechanical damage to the cover.
- Regularly (preferably weekly) check biogas production and methane content. This is the most rapid and reliable means of assessing the health of the CAL. If the facility triggers the NGERS reporting threshold, good and consistent records will be needed regarding biogas volumes processed through the flare for the annual NGERS reporting.
- Ensure regular long term checks and maintenance are performed on the elements of the biogas capture system according to the manufacturer's instructions.
- Liaise and report (as needed) to appropriate State regulatory authorities (note that this may not be the Environment Protection Authority (EPA)) regarding the biogas capture system.

Available training programs

IWES, owned by the University of Queensland, offers a five day course run annually on the Gold Coast and Sydney entitled 'Principles of waste water treatment'.

Water Training Australia offers a number of courses that relate to waste water operations and can be undertaken as individual units or as a package to suit your needs. Some of these units include:

- NWP207A Work effectively in the water industry
- NWP208A Perform basic wastewater tests
- NWP218B Perform sampling
- NWP221A Operate basic flow control and regulatory devices in water or waste water treatment network systems
- NWP262A Monitor and report wastewater treatment processes
- NWP346B Monitor, operate and control wastewater treatment processes
- NWP352B Monitor, operate and control dissolved air flotation processes

INFORMATION FOR TRAINERS

Why is training for waste water operators and managers important?

Significant research has been undertaken on best practice for waste water management, with numerous research reports available. However to date, the information contained in the reports has not been collated into a simple 'how to' manual for personnel responsible for the day-to-day management of anaerobic and aerobic ponds.

Meat processing waste water can be difficult to treat properly compared to other industrial waste waters. As such, training for operators and managers is vital.

Money spent on training is an investment by the company and must provide real returns. These returns might be in terms of money saved through less waste, through reduced staff turnover or through the company's ability to retain an export licence. Training for training's sake, or training not clearly matched to a company's goals is often costly and of limited value.

What accredited training is available for waste water operators and managers?

1. Certificate III in Water Operations

This is a nationally recognised qualification for water or wastewater treatment plant operators. It provides industry-focused training in monitoring and coordinating treatment processes to protect public health and the environment. To achieve this qualification the candidate must demonstrate competency in 11 units of competency, comprising three core and eight elective units.

2. Meat Processing Environmental Officer Skills Set

This skills set has been developed to address the need to offer formal training for people charged with managing the environmental issues at a processing plant. This Skills Set contains the following Units of Competency:

- MTMPSR202B *Apply environmentally sustainable work practices*
- MTMCOR204A *Follow safe work policies and procedures*
- MTMCOR206A *Overview the meat industry*
- NWP262A *Monitor and report wastewater treatment processes*
- NWP263A *Operate and maintain wastewater treatment plant and equipment*
- MSL973001A *Perform basic tests*
- MSL954001A *Obtain representative samples in accordance with sampling plan*

3. Waste Water Skills Set

This Skills set is currently under development. The Waste Water Project National Steering Committee has identified a number of units of competency which could be developed as a Skill Set which would; then lead into a Certificate III in Waste Water Operations.

4. Individual units of Competency

The following list of units has been identified for accredited training for Waste Water operators in the meat industry. After successful completion of these individual units a statement of attainment can be awarded by the delivering Registered Training Organisation.

Units:

QUALIFICATION CODE	TITLE
MTMPSR202B	Apply environmentally sustainable work practices
MTMCOR204A	Follow safe work policies and procedures
MTMCOR205A	Communicate in the workplace
NWP208A	Perform basic wastewater tests
NWP262A	Monitor and report wastewater treatment processes
NWP263A	Operate and maintain wastewater treatment plant and equipment
NWP303A	Monitor and control maintenance of water and wastewater system assets
NWP305B	Monitor and conduct minor maintenance on complex flow control and metering devices
NWP308B	Test and commission wastewater collection systems
NWP311B	Monitor and operate wastewater collection and transfer systems
NWP345B	Monitor, operate and control water treatment processes
NWP346B	Monitor, operate and control wastewater treatment processes
NWP350B	Monitor, operate and control trickling filter processes
NWP351B	Monitor, operate and control activated sludge processes
NWP353B	Monitor, operate and control anaerobic bioreactor processes
NWP357B	Monitor, operate and control reverse osmosis and nano-filtration processes
NWP359B	Monitor, operate and control nutrient removal processes
NWP362B	Monitor, operate and control reclaimed water irrigation
NWP363B	Monitor performance and control maintenance of treatment plant assets
NWP366A	Monitor, operate and control chloramination disinfection processes

Available training and assessment support materials

MINTRAC has developed Training and Assessment Support Materials for all Units of Competency in the *Australian Meat Industry Training Package*. Training and Assessment Support Materials are already available for MTMPSR202B *Apply environmentally sustainable work practices* and materials for NWP208A *Perform basic wastewater tests* and NWP262A *Monitor and report wastewater treatment processes* will be available by December 2012.

This kit will support the delivery of the Certificate III in Waste Water Operations but will not satisfy the training and assessment requirements for the whole qualification.

Supplementary materials

Over the past few years, AMPC and MLA have undertaken a considerable body of research around the waste water treatment in the Australian meat industry.

MLA (2007). *Environmental best practice guidelines for the red meat processing industry.* Module 3. Eds. M Johns, S McGlashan & A Rowlands. North Sydney.

Provides useful descriptions of best practice wastewater technologies for upstream treatment.

MLA (2003). *Assessment of hydrocyclones for fat removal from meat processing wastewater streams.* Project PRENV.022, prepared by GHD. North Sydney.

Provides useful assessment and data on use of hydrocyclones in meat plants for fat recovery.

MLA (2009). *Solids removal and grit recovery by hydrocyclone*. Project P.PSHP.0363, prepared by Johns Environmental. North Sydney.

Provides useful assessment and data on use of hydrocyclones in meat plants for grit removal from stockyard streams.

MLA (2007). *Environmental best practice guidelines for the red meat processing industry*. Module 3. Eds. M Johns, S McGlashan & A Rowlands. North Sydney.

Provides useful descriptions of best practice wastewater technologies for anaerobic treatment.

MLA (2011). *Learnings from the Burrangong Meat Processor covered anaerobic lagoon*. Project A.ENV.0089, prepared by Rycam Industrial. North Sydney.

Provides insightful comment on challenges associated with covering anaerobic lagoons and how to overcome them.

MLA (2009). *Anaerobic cover material vulnerability*. Project A.ENV.0072, prepared by Golder Associates. North Sydney.

A comprehensive technical study of several CAL cover failures under Australian conditions and an assessment of various cover materials.

Several useful reports are imminent from MLA during 2012 relating to a CAL case study at King Island and to biogas quality across several recent CAL installations in Australian red meat plants.

In addition, MLA has produced the following kits:

- Environmental Best Practice Guidelines for the Red Meat Processing Industry
  – http://www.redmeatinnovation.com.au/project-reports/report-categories/environment/environmental-best-practice-guidelines-for-the-red-meat-processing-industry
- Eco-Efficiency Manual for Meat Processing
  – http://www.redmeatinnovation.com.au/project-reports/report-categories/environment/eco-efficiency-manual-for-meat-processing
- Red Meat Processing Industry Energy Efficiency Manual
  – http://www.redmeatinnovation.com.au/project-reports/report-categories/environment/red-meat-industry-energy-efficiency-manual

Other industry research.

RIRDC (2008). *Assessment of Australian Biogas Flaring Standards*. Project PRJ-000874, prepared by GHD. RIRDC, Canberra. An excellent publication reviewing biogas flares, their issues, types, costs and regulation.

MSDS for methane. Can be obtained off the web and is a useful read.

SIWA (2005). *Field procedures handbook for the operation of landfill biogas systems*. Prepared by Working Group for Sanitary Landfills, International Solid Waste Association, Copenhagen. An useful and practical guide for working with biogas systems. Not all of the material is relevant, but the bulk of it is applicable.

DCCEE (2011). *Technical guidelines for estimation of greenhouse emissions by facilities in Australia*. Published by Dept. Climate Change & Energy Efficiency, Canberra, July 2011. For the brave-hearted, this manual documents legislated means by which greenhouse emissions must be estimated. Contains a section (Part 5.4) on industrial wastewater emissions and flaring.

Customising the MINTRAC Training materials

Every meat processing company is different. The training and assessment should match the operations of the company and the requirements of the units of competence. The material in this kit must be customised to the company's and trainee's needs by including the:

WI	Company **work instructions** for the tasks in the material.
SOPs	Company **standard operating procedures** for the tasks in the material.
E	Company **equipment** used for the tasks in the material.
D	Any company **documents** or forms used for the tasks in the material. This includes safety signs, Material Safety Data Sheets (MSDSs), quality assurance checklists and company memos.

Customisation of these materials is essential. Customisation means that trainers and assessors must check:

- that information from company Work Instructions and SOPs is considered
- that the training materials and activities are adjusted to ensure that company requirements and learner's needs are addressed
- that the assessment tools are adjusted to ensure that company requirements and learner's needs are addressed
- that changed assessment tools are mapped to the Unit of Competency in the Evidence Guide to ensure that of the requirements of the Units of Competency are addressed.

The support materials can be used by ***trainers*** to:

- plan and deliver training
- give additional information to trainees
- keep a record of the training they have delivered.

The support materials can be used by ***assessors*** to:

- plan assessment – after training and for recognition of current competence/prior learning
- show trainees the areas they need to work on to be competent
- keep a record of the evidence used in assessment.

Some parts of the training materials can be used by ***trainees***:

- as a resource during training
- to review knowledge, understanding and learning
- to prepare for assessment.

Overview of possible delivery structures

This kit contains:

- written materials
- ebook.

How can trainees use ebook?
Accessing ePub?
How to download the ePub to your tablet device or smart phone

1. Install an ePub reader application on your tablet device or smart phone
2. Go to 'name location where the ePub is stored on your network', select the 'name of link' and then download the ePub to your tablet device or smart phone.
3. Activate the ePub reader on your device and then open the ePub.
4. Browse the ePub.

How to transfer the ePub from your computer to your tablet device or smart phone

Install an ePub reader application on your tablet device or smart phone

1. On your computer, go to 'name location where the ePub is stored on your network', select the 'name of link' and then download to your computer.
2. Connect your tablet device or smart phone to your computer.
3. Copy the ePub from your computer to your tablet device or smart phone
4. Disconnect your tablet device or smart phone from the computer
5. Activate the ePub reader on your device and then open the ePub.
6. Browse the ePub.
7. Need to contact IT for details on where the ePub is to be stored within your network/IT infrastructure and modify the instructions accordingly

Providing electronic on-line support

- Computer managed learning

This is learning which is presented through a computer and which is sometimes also scored or marked by the computer, which then provides feedback to the learner. Computer based learning is useful where guided learning through complex issues or structures is required. Trainers should take into account the learner's previous experience with computers, capacity to undertake self-directed learning, and the amount of monitoring and support the learner will need to successfully complete the program. Computer-based learning is not often used with learners in lower-level qualifications, although sometimes computer-based learning resources are used in addition to other strategies.

Work experience opportunities to complement delivery of particular Units

These involve a visit to a site or an actual real-life example of the subject matter, such as a saleyards, lairage or another workplace site. In a meat processing plant, these visits are most likely to be used during an induction program. A field trip or visit needs to be carefully planned and arranged beforehand, both in terms of the visit site and the learners. Learners should be provided with guidelines and objectives for the visit or it becomes a sightseeing tour. Provide specific questions to be answered, issues to be addressed, observations to be drawn or problems to be solved. Trips need to be debriefed and discussed afterwards to bring out the learning points.

On site mentoring arrangements

Mentoring is a long term process to develop individuals within an organisation. It can be used both in-house and externally, and can be useful for the professional development of junior individuals and a guiding process with organisational cultural issues.

The role of the mentor is to help the mentee develop the necessary skills, knowledge, experience, and personal attributes to be successful. This might be within a specific field or career, or a more generally in life.

Within a work setting, mentors are used in a number of ways. Generally, a more experienced person is paired with a less experienced, or newer employee and is someone other than their direct manager. For example, the senior Environmental Engineer on site might be paired with an Environmental graduate. The senior Environmental Engineer will provide help to the graduate, assist with specific projects, or provide advice and support to assist them achieve specific work related goals and objectives.

Some of the benefits of providing mentoring in the work place are:

- improving individual performance
- improving employee retention rates
- developing greater co-operation
- improving knowledge sharing
- improving employee morale
- succession planning
- encourage reflective learning
- improving work place communication.

Notes

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