AMPC

Wastewater Management in the Australian Red Meat Processing Industry

Version 2

PROJECT CODE:	**2017 (A.ENV.1027)**
PREPARED BY:	**This manual is an updated version of 2012 Wastewater Management in the Australian Red Meat Processing Industry Manual produced by Johns Environmental Pty Ltd and MINTRAC with funding from the Australian Meat Processing Corporation and the Environment and Biotechnology CRC (EBCRC).** **The update includes the addition of two new chapters. Chapter 1 was prepared by The Ecoefficiency Group and Chapter 5 by Johns Environmental Pty Ltd.**
DATE SUBMITTED:	**15th Feb 2017**

The Australian Meat Processor Corporation acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

TABLE OF CONTENT

ABBREVIATIONS

CHEMICAL ABBREVIATIONS

Term	Meaning
AMPC	Australian Meat Processor Corporation
AAR	Anaerobic Ammonium Removal
ACR	Anaerobic Contact Reactor
AOB	Ammonia Oxidising Bacteria
BNR	Biological Nitrogen Removal
BOD	Biological Oxygen Demand
BOD_5	5-day Biological Oxygen Demand
CAL	Covered Anaerobic Lagoon
COD	Chemical Oxygen Demand
DAF	Dissolved Air Flotation
DWAS	Dewatered Waste Activated Sludge
DO	Dissolved Oxygen
EC	Electrical Conductivity
EPA	Environmental Protection Authority
GPW	Global Warming Potential
FOGs	Fats, oils and greases
HACCP	Hazard Analysis and Critical Control Points
HSCW	Hot Standard Carcass Weight
MLA	Meat and Livestock Association
MLSS	Mixed Liqueur Suspended Solids
NGERS	National Greenhouse and Energy Reporting System
NP	Negative Pressure
NOB	Nitrite Oxidising Bacteria
PP	Positive Pressure
RAS	Return Activated Sludge
RIDDC	Rural Industries Research and Development Corporation
SBR	Sequence Batch Reactor
SND	Simultaneous Nitrification Denitrification
TA	Total Alkalinity
TSS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
VFA	Volatile Fatty Acids
WAS	Waste Activated Sludge
WWTP	Wastewater Treatment Plant
Term	**Meaning**
$CaCO_3$	Calcium Carbonate (Lime)
CH_4	Methane gas
CO_2	Carbon Dioxide gas
H_2	Hydrogen gas
H_2S	Hydrogen Sulphide gas
N	Nitrogen
N_2O	Nitrogen Dioxide gas
NO_2^-	Nitrite
O_2	Oxygen gas
P	Phosphorous
PO_4^{3-}	Inorganic phosphate
TA	Terephthalic acid

TN	Total Nitrogen
TP	Total Phosphorous
NaCl	Sodium Chloride (salt)
NH4	Ammonia

UNITS

Term	Meaning
Km	Kilometres (length)
kL	Kilolitre (volume)
Kpa	Kilopascal (pressure)
m^3	Cubic metre (area)
Pa.g	Pascals per gram (Pressure)
pH	Potential of Hydrogen (scale of acidity or basicity)
T	Tonne (weight)

1.0 REDUCING WASTEWATER VOLUMES AND LOADS

1.1 Sources of wastewater

1.1.1 Water usage and the true cost of water consumption

The majority of plants obtain their water from town water sources or bores and are large water users. Water consumption ranges from 5.7 to 12.7 kL/t HSCW cattle equivalent (Ridoutt, 2015) with the large variation in water usage not only related to water efficiency practices but also:

- Product market and export requirements.
- Type of animal processed
- Amount of value adding that is performed e.g. sold as wholesale boxed meat sides or retail packs
- Number and length of shifts
- Meat processing plant layout and design
- Age and variation in processing equipment

1.1.2 Sources of wastewater

About 85% of fresh water intake in a meat processing plant will become wastewater. As Table 1 indicates the slaughter and evisceration areas consume the largest amount of water with the majority being used for cleaning and sterilising equipment.

When looking at the characteristics of wastewater both volume and pollutant load should be considered. The volume will affect the hydraulic loading of downstream wastewater treatment systems while pollutants in the wastewater can negatively impact on the receiving environment of treated wastewater.

Table 1: Typical water consumption in a meat processing plant and typical flow and strength (GHD Pty Ltd, 2005)

<table>
<tr><th>Key areas of water consumption</th><th>Percentage of total fresh water consumption</th><th>Flow volume</th><th>Strength</th></tr>
<tr><td>Stockyards and truck washing</td><td>7 - 24%</td><td>Medium</td><td>High</td></tr>
<tr><td>Slaughter and evisceration</td><td>44 - 60%</td><td rowspan="2">High</td><td rowspan="2">Low</td></tr>
<tr><td>Boning</td><td>7 - 38%</td></tr>
<tr><td>Inedible and edible offal processing</td><td>9 - 20%</td><td rowspan="2">Medium</td><td rowspan="2">High</td></tr>
<tr><td>Casing processing</td><td>2 - 8%</td></tr>
<tr><td>Rendering</td><td>2 - 8%</td><td>Low</td><td>Very High</td></tr>
<tr><td>Chillers</td><td>2%</td><td rowspan="3">Low</td><td rowspan="3">Low</td></tr>
<tr><td>Boiler losses</td><td>1 - 4%</td></tr>
<tr><td>Amenities</td><td>2 - 5%</td></tr>
</table>

1.1.3 Wastewater characteristics

Materials that typically enter the wastewater stream and add to pollutant load include:

- **Organics comprising BOD, COD, TSS, oil and grease**
  If wastewater treatment is not well managed it is the degradation of these organics by bacteria that can cause odour issues.
- **Nitrogen (N) and Phosphorous (P)**
  The disposal route for the wastewater will determine the level of treatment required to remove these nutrients. For example, if irrigating pasture or using wetlands as treatment it may be necessary to only partially remove the nutrients; while complete removal is typically required for discharge to water bodies.
- **Salt (typically NaCl)**
  Salt enters wastewater streams via urine, some water supplies (e.g. bore water) and cleaning chemicals. The removal of salt is particularly important where wastewater is irrigated as the concentration of salt can be detrimental to soils and nearby water bodies.
- **Micro-organisms**
  The presence of pathogenic (disease forming) and non-pathogenic microorganisms from animal manure and paunch.
- **Chemicals**
  Chemicals such as surfactants and chlorine from cleaning and disinfection agents which impact on the pH of wastewater.

The temperature of wastewater from meat plants also varies widely from hot to cool. Fats may liquefy in water greater than 38°C and as a result may not be captured by primary treatment processes.

These pollutants not only impact on the level and cost of treatment but also signify the loss of valuable resources. Table 2 shows the materials that typically contribute to pollutant load in meat processing plant wastewater.

Table 2: Materials that contribute to pollutant load in meat plant wastewater (MLA, 2003)

Source of pollutants	Chemical Oxygen Demand (COD)	Nitrogen (N)	Phosphorus (P)	Sodium (Na)	Total Suspended Solids (TSS)	Oil and grease
Fat	✓				✓	✓
Yard manure	✓		✓		✓	
Paunch manure	✓		✓		✓	
Blood	✓	✓	✓			
Meat tissue		✓				
Urine		✓		✓		
Fresh water				✓		
Recycled water				✓		
Pickling brine				✓		

Wastewater streams are typically classified as ‘green’ or ‘red’. Green streams are initially treated separately to red streams and are generated from manure and paunch wastes from the emptying of the animal stomach and internal organ processing. This stream accounts for about half of the total phosphorus and sodium contaminants.

Red streams are generated from the slaughter, evisceration and boning areas as well as any rendering processes. These streams contain fat and nitrogen from blood, urine and proteins from meat tissue.

1.1.4 Wastewater minimisation strategies

It is easy to underestimate the cost of water and wastewater treatment. In addition to purchase price, the full cost of water includes any incoming treatment and then final treatment and disposal. The full cost of wastewater treatment can also include electricity cost for pumping, equipment operation, aeration and mixing during treatment etc., chemical costs such as those for pH balancing and flocculation and sewer discharge fees.

Image 1: Full cost of wastewater treatment should include electricity cost for pumping and aeration
Australian County Choice, Cannon Hill

Water consumption also equates to energy consumption with 30-40% of water used being either warm (43°C) or hot (82°C) because food safety regulations stipulating high temperature requirements in certain areas. (GHD Pty Ltd, 2005)

Another benefit of reducing water consumption can be the recovery of cleaning chemicals which previously may have been lost to wastewater streams. This has the added benefit of lowering effluent strength, further reducing treatment costs and discharge fees.

In order to reduce water and wastewater costs, it makes sense to take measures to reduce water consumption and minimise volumetric and pollutant waste loads as far as possible. Opportunities include:

Cleaning

- Good workplace design and layout (e.g. smooth and impervious floors and walls, easy-to-clean, self-draining and correctly-sized drains, slip-resistant floors made of appropriate strength material and sloped to drains)
- Schedule production to reduce cleaning requirements and minimise equipment in use e.g. number of knifes needing sterilization
- Operator training and adequate, readily accessible, dry cleaning equipment
- Use low flow / high pressure water after dry-cleaning (only suitable for areas where aerosols are not a problem)
- Monitor and replace worn hand held triggers on hoses. Ensure they are easily accessible and the diameter of the hose is appropriate for the task
- Use floor cleaning machines for large areas
- Install electrical sensors on hand and apron wash stations (if an electrical supply does not pose a problem)
- Optimise spray nozzles on hand, boot and apron washers

Stock washing

- Use non-potable water for prewash
- Operator training and monitoring
- Screen effluent before it enters the wastewater treatment system

Stockyard washing

- Dry cleaning of manure before floor washing
- Suspended mesh flooring of stock to allow for easier cleaning (for hard hooves animals)
- Use non-potable water for wash down
- Operator training and monitoring
- Screen effluent before it enters the wastewater treatment system

Knife sterilizers

- Insulating sterilisers and drop pipe to reduce heat loss and therefore water use
- Fixing continuous flow sterilisers to a minimum flow rate if the temperature and pressure are relatively constant
- Install a shut off value to discontinue flow at the end of sterilisers at the close of operations
- Reuse knife steriliser wash water to wash cattle and yards
- Spray sterilisers an option if used infrequently

Evisceration tables

- Install on and off controls linked to a sensor to ensure sprays only flow when required
- Determine the minimum flow rate required to effectively clean and sterilise tables
- Optimise and maintain spray nozzles
- Improve the design of the moving table so less cleaning is required
- Install a Clean-In-Place system using water efficient pumps
- Steriliser water collected from clean end on the viscera table and used for the initial viscera table wash
- Initial rinsing of paunch contents if they are wet dumped

Carcass washing

- Manual - ensure operators are trained as efficacy is directly related to the skill and motivation of operator
- Automated systems - Optimise flow rates, dwell times, temperatures and spray nozzle performance and monitor (recirculate and treat hot water for reuse)
- Chemical treatment - Consider using chemical rinses if they meet hygiene standards

Inedible and edible processing

- Replace wet paunch dumping with dry paunch dumping
- Install flow meters on tripe and bible wash machines
- Install more water efficient tripe and bible wash machines
- Ensure casing machines do not run unnecessarily
- Recycled water used for gut washing
- Replace shower roses on offal wash stations with efficient roses or spray nozzles

Automatic container washer

- Investigate using purpose built automatic washers to clean containers, rather than manual hoses or high pressure cleaning methods
- Reuse final rinse water for pre-rinses cycles
- Adjust washer speed and length of cleaning cycles to achieve the most efficient clean while meeting hygiene standards

Boilers

- Install conductivity sensors and check that blowdown is initiated only when necessary
- Return steam condensate to the boiler
- Inspect and maintain steam traps and condensate lines regularly

Cooling towers

- Optimise cycles of concentration to reduce blowdown losses (to safe levels depending on quality of makeup water)
- Clean conductivity probes and recalibrated regularly
- Consider additives such as softeners of acid to minimise blowdown

Stormwater

- Exclude uncontaminated stormwater from the waste treatment areas to reduce volumetric loads

1.2 Wastewater treatment and disposal routes

The choice of whether a meat processing plant disposes of treated wastewater to sewer; surface water bodies or land irrigation will depend on the plant's location i.e. rural or urban with residences nearby; and its surrounding environment e.g. available land to irrigate or the presence of suitable nearby waterways.

The choice of disposal will impact on the level of treatment required. There are three main wastewater treatment levels.

- Primary treatment to remove suspended solids and oil and grease.
- Secondary treatment to remove nutrients, organics and pathogens.
- Tertiary treatment for disinfection.

The required regulatory disposal standard varying from state to state and local jurisdictions.

1.3 Wastewater reuse

Reuse opportunities for treated wastewater can reduce water consumption. Australian Standards and the 2008 Meat Notice issued by the federal controlling quarantine and inspection authority state that only potable water can be used for the production of meat and meat production unless the water is only used for:

- Steam production, which is not direct or indirect contact with meat or meat products
- Fire control
- Cleaning of yards
- Washing of animals (other than final wash)
- Similar purposes not connected with meat and meat products e.g. cleaning around wastewater treatment plant, inedible offal processing and in other circumstances where there is no risk of the water coming in contact with or contaminating meat and meat products. For example:
    - Cooling tower makeup
    - Boiler makeup
    - Outdoor paved area cleaning
    - Watering of landscaped areas
    - Cattle truck washing.

An approved arrangement must provide for the use of non-potable water. Approved arrangements are those approved by the federal controlling authority and provide for the implementation of a HACCP (Hazard Analysis and Critical Control Points) plan.

HACCP is a systematic preventive approach to food safety and ensures that at critical control points in the process parameters are measured to ensure any biological, chemical or physical hazards that could cause the product to be unsafe are within set limits.

The treated water must meet the Australian Drinking Water Guidelines for potable water and must exclude human effluent from the waste water stream to be treated. There must be no physical connection between the potable and any other non-potable supply.

2 UPSTREAM WASTE WATER TREATMENT

2.1 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.

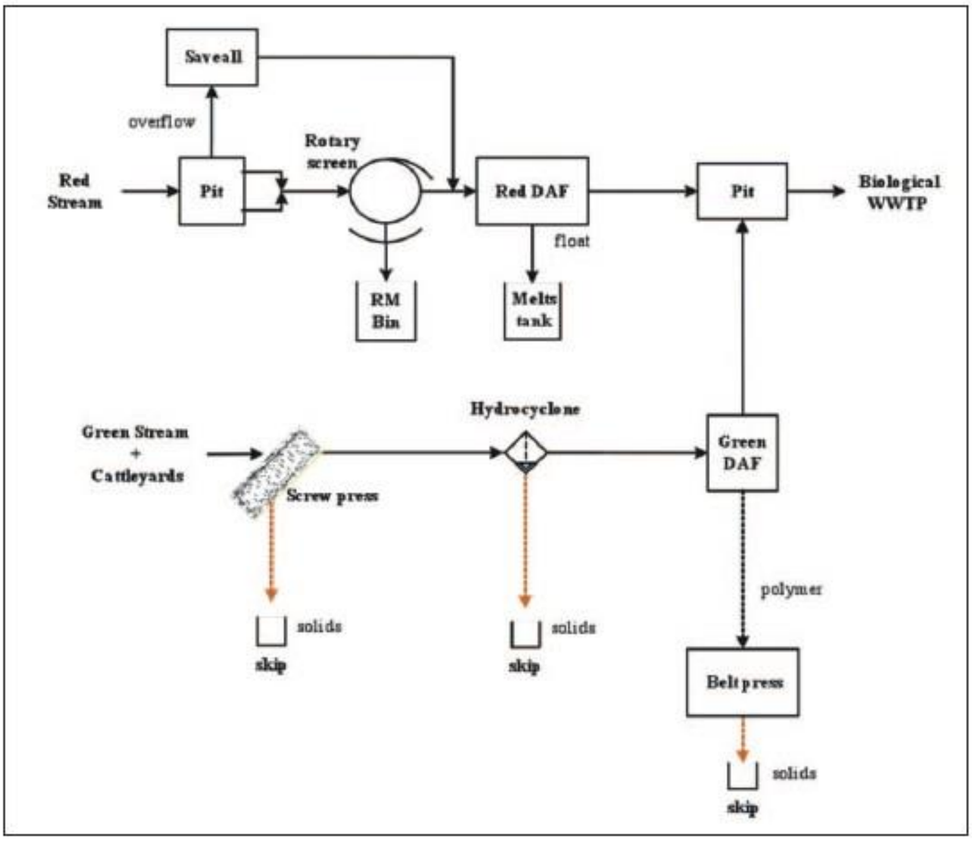


Figure 1: Typical arrangement of upstream technologies in meat processing plants

2.2 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.

2.2.1 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.

Image 2: Static screen
Meramist, Caboolture

2.2.2 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.

Image 3: Rotary screen
Australian Country Choice, Cannon Hill

2.2.3 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.

Image 4: Screw press
Hydroflux HUBER©

2.2.4 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.

Image 5: Degritting hydrocyclone
Johns Environmental©, Teys, Wagga Wagga

Table 3 provides an overview of each of the technologies in the context of treating meat processing waste water.

Table 3: 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)

Issue	Static screen	Rotary screen	Screw press	Degritting hydrocyclone
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

2.3 Reducing oil and grease

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

2.3.1 Saveall

2.3.2

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.

Image 6: Saveall tank
JBS Dinmore

2.3.3 Undosed Dissolved Air Flotation unit (DAF)

An undosed DAF 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.

Image 7: Dosed Dissolved Air Flotation unit
NB Foods, Oakey

2.3.4 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 chemicals 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.

2.3.5 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.

Image 8: Deoiling hydrocyclone
Johns Environmental, XXXXXX

Table 4 presents information for these technologies as applied to meat processing effluent

Table 4: 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

2.4 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.

Image 9: Balancing tank
ACC, Cannon Hill

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.

Recommended day-to-day operator responsibilities are described in Table 5.

2.5 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).

2.6 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 programmable logic controller 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.

2.7 Operating and maintaining upstream systems

2.7.1 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 5

Table 5: 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 build-up 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 build-up in the DAF if bottom scrapers are not fitted.
Dosed DAF.	• As for DAFs above. • Monitor coagulant and polymer inventory and dosing

2.7.1.1 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.

2.7.1.2 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 **5** 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.

2.7.1.3 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.

2.7.1.4 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.

2.7.2 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.

3 ANAEROBIC PONDS AND REACTORS

3.1 Overview of anaerobic ponds & reactors

3.1.1 How they work

Anaerobic ponds and reactors 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 (BOD_5), 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 twostep 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 BOD_5 and COD of the water are reduced.

There are four important things to know about anaerobic systems:

1. They 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 (NH_3)
   - hydrogen sulphide (H_2S)
   - 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 and reactors. No supplement can be added to prevent this without killing the pond.

2. Anaerobic systems 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 systems 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 has significantly adopted 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.

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

Table 6 contrasts the positive and negatives of anaerobic ponds

Table 6: 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	

3.2 Types of anaerobic ponds

3.2.1 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:

Image 10: Natural crusted pond
NB Foods, Oakey

- 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.

3.2.2 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:

Image 11: Covered anaerobic lagoon
Teys, Beenleigh

- 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).

CALs are designed to operate either under positive pressure (PP) or negative pressure (NP). PP systems are currently the preferred option of most Australian meat processing plants. PP systems allow generated biogas to accumulate under the lagoon's cover typically at pressure setpoints between 10 – 75 Pa.g. The inflated cover provides insulation, acts as a gas storage device while the dome shape helps to shed rainwater and reduces the likelihood of air ingress. The distinctive smell of biogas around a PP CAL may indicate a loss of integrity in the covering system. PP systems are able to handle sizeable liquid level variations.

Negative pressure CALs are designed to operate at negative pressures (< 0 Pa.g) and allow no build-up of biogas. Consequently, the cover will lie flat on the water surface of the lagoon at all times unless there is a failure in blower suction. A biogas fan or blower removes the biogas typically into an adjacent storage device. NP covers are subjected to less strain than NP covers but this benefit must be weighed against the deterioration of the cover as a result of contact with volatile fatty acids in the liquid and risk of air ingress causing potentially explosive biogas/air mixtures.

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.

Answer
Typical sludge generation for these two systems is:

a) Anaerobic ponds: 0.05 - 0.1 kg sludge/kg COD removed
b) Aerated ponds: 0.5 - 0.6 kg sludge/kg COD removed

a) 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/m3:
Wet sludge volume (m3/day) = 13,500/1,000
= 13.5 m3/day of wet black stuff every production day!

How much a year? If 240 processing days/year:
Wet sludge (m3/year) = 13.5 x 240 = 3,240 m3/year.

b) 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/d] * 0.5 [kg sludge/kg COD removed]
= 3,375 kg/day

This is dry sludge though. 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 say 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? Say 240 processing days/year:
Wet sludge (m^3/year) = 67.5 * 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.

3.2.3 Mixed Vessel Anaerobic Reactors

Rather than using an earth dam, the anaerobic reaction can be contained in a suitably constructed tank or vessel if mixing is provided. The much higher cost of tanks relative to dams in Australia has limited the application of vessel reactors to smaller plants.

The Anaerobic Contact Reactor (AC) for example uses an activated sludge-type process in which the wastewater is fed into a large, mixed reaction tank where high concentrations of microbial sludge are maintained. The treated water flows out of the tank into a degassing chamber, where high levels of dissolved biogas are removed and then enters a clarifier where the bacterial sludge is settled out. Most sludge is returned to the upstream reaction tank to maintain high bacterial levels with the excess sent to waste.

Such reactors offer somewhat higher COD loadings than CALs or anaerobic ponds, but still low relative to common high rate anaerobic reactors used in other industries such as breweries. This is due to the particulate nature of meat processing wastewater, in which the rate limiting step is the hydrolysis of the particulate material to provide soluble food to the bacteria.

The constructed reactors require substantial equalisation volume upstream to ensure their process stability, whereas the larger CALs do not require this.

3.3 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 that are liable to pay for emissions under the Carbon Pricing Mechanism. 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.

3.4 Establishing anaerobic ponds

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. 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. Volatile fatty acid (VFA) to total alkalinity (TA) ratio is 0.25 or less.

3.5 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.

3.6 Operating and maintaining anaerobic ponds

3.6.1 Operator responsibilities

3.6.1.1 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 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 stress 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.

Image 13: Stormwater removal system off CAL cover
Teys, Beenleigh

3.6.1.2 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.

3.6.1.3 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, oil and grease.

Table 7 suggests optimal and sub-optimal ranges for these parameters. These numbers are a guide only.

Table 7: Recommended operating ranges for anaerobic ponds

Parameter	Preferred range	You're in trouble
Temperature	20 – 37°C	More than 40°C Less than 10°C
pH	6.7 – 8.0	Less than 6.5
EC	Less than 3,000 µS/cm	More than 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

3.6.1.4 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 bubbles 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.

3.6.1.5 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.

3.6.1.6 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.

3.6.2 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.

4 AEROBIC PONDS

4.1 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 BOD_5 concentrations to levels suitable for irrigation to land without odour (typically BOD_5, 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 8.

Table 8: Characteristics of aerobic ponds

Parameter	Aerated ponds	Facultative Ponds	Maturation Pond
Usual depth (metres)	2 - 4	< 3	< 1.5
Aeration	Mechanical	Top layer aeration/algae/wind	Algae/wind
Anaerobic layer?	No	Yes	No
Sludge production	High	Medium	Low
Risk of odour	Unusual	Possible	Unlikely

4.2 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 (DO) levels and musty smelling
- A deeper anaerobic layer which performs exactly like an anaerobic pond.

Image 14: Facultative Ponds
Johns Environmental, XXXX

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 a meat processing plant 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 shows the layout of a facultative pond. The interface between the layers moves up and down according to the amount of aeration of the top layer.

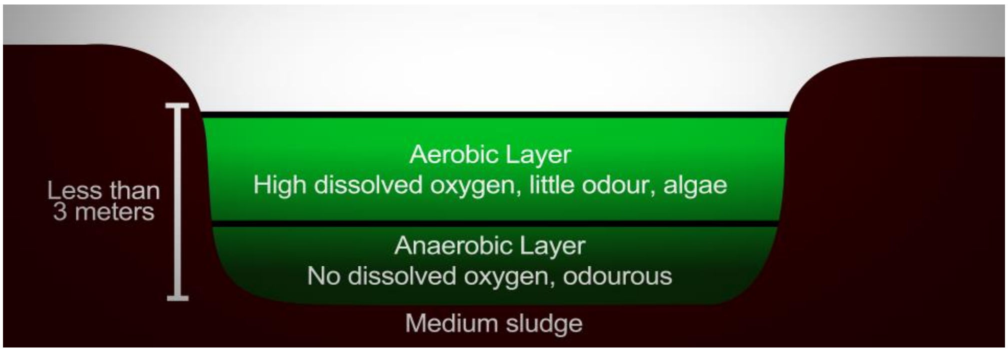


Figure 2: Layering in a facultative pond.

The advantages and challenges of a facultative pond are compared in Table 9**Error! Reference source not found.**.

Table 9: Characteristics of facultative ponds

Positives	**Negatives**
Good removal of organic load	Can smell badly 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	

4.3 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.

Image 15: Aerated pond

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 10 summarises the benefits and downsides of aerated ponds.

Table 10: 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	

4.4 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, which is a good thing in terms of providing a rich DO concentration and high pH (> 7.5) in the water. This help kill pathogens.

Image 16: Maturation ponds
NB Foods, Oakey

For maximum effectiveness, two smaller ponds are superior to one large one. The benefits and problems with these ponds are described in Table 11.

Table 11: 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	

4.5 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 that are liable to pay for emissions under the Carbon Pricing Mechanism. 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.

4.6 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.

4.6.1 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:

- 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
- DO level is more than 2mg/L

- No unpleasant smell.

4.6.2 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.

4.7 Operating and maintaining aerobic ponds

4.7.1 Operator responsibilities

The following day to day operator responsibilities are recommended:

4.7.1.1 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).

4.7.1.2 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).

4.7.1.3 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.

4.7.1.4 Diagnostics

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

Image 17: Mousse on aerated pond
Australian Country Choice, Cannon Hill

- **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).

4.7.1.5 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.

4.7.1.6 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.

4.7.2 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.

5 NUTRIENT REMOVAL

5.1 Overview

Nitrogen and phosphorus is present in meat processing wastewater in several forms and are pollutants termed a "nutrient", since they are essential elements for life. They largely derive from proteins dissolved into wastewater from meat tissue, blood (nitrogen), paunch liquid and stockyards.

Both nitrogen and phosphorus are stringently regulated in Australia regardless of the receiving environment. Typical regulatory limits are provided in Table 12. These limits define the levels that the wastewater treatment plant (WWTP) must reliably achieve and to some extent which treatment technologies are most appropriate.

Table 12: Typical regulatory limits for nutrients

Receiving environment	Nitrogen	Phosphorus
Sewer	NH_3 ≤ 50 mg/L TN ≤ 100 mg/L	TP ≤ 10 – 20 mg/L
River discharge	NH_3 ≤ 1 mg/L TN ≤ 50 - 100 mg/L (site specific) Also typically load based limits	TP ≤ 1 - 40 mg/L (very site specific)
Land irrigation (soil & crop specific)	TN: 250 – 500 kg/ha/yr load based limits	TP: 30 – 40 kg/ha/yr load based limits

Regulatory limits vary widely throughout Australia. For river discharge, they are usually negotiated on a site-specific basis taking the limiting nutrient of the river system and the catchment assimilation capacity into account. In many parts of Australia, direct river discharge is not an option. Some limits are concentration based, others may be expressed as load (mass) based limits, especially for land irrigation

5.1.1 Nitrogen removal technologies

A range of technologies exist for reducing nitrogen concentrations in meat processing wastewater with biological nitrogen removal (BNR) activated sludge technology and chemically dosed DAFs being the most widely applied. Table 13 summarises properties of the various technology options. Dosed DAF technology is commonly used for sewer discharge, while bacterial BNR processes are preferred for river discharge and land irrigation where nitrogen limits are strict. This section focusses on biological nitrogen removal.

Anaerobic Ammonium Removal (AAR) technology and struvite (see phosphorus removal section) are emerging technologies which have not been proven at large scale in meat plants and will be covered only briefly.

Biological nitrogen removal is the dominant large scale technology employed in Australian meat processing plants and can be harnessed in a range of reactor types including:

- Sequencing Batch Reactors (SBR) where an intermittent mode of activated sludge operation (time-based) is used to reduce nitrogen
- Continuous BNR which uses a continuous flow technology and clarifiers for sludge settling and separation from the bacterial floc
- Aerated ponds which are a less intensive form of continuous BNR systems

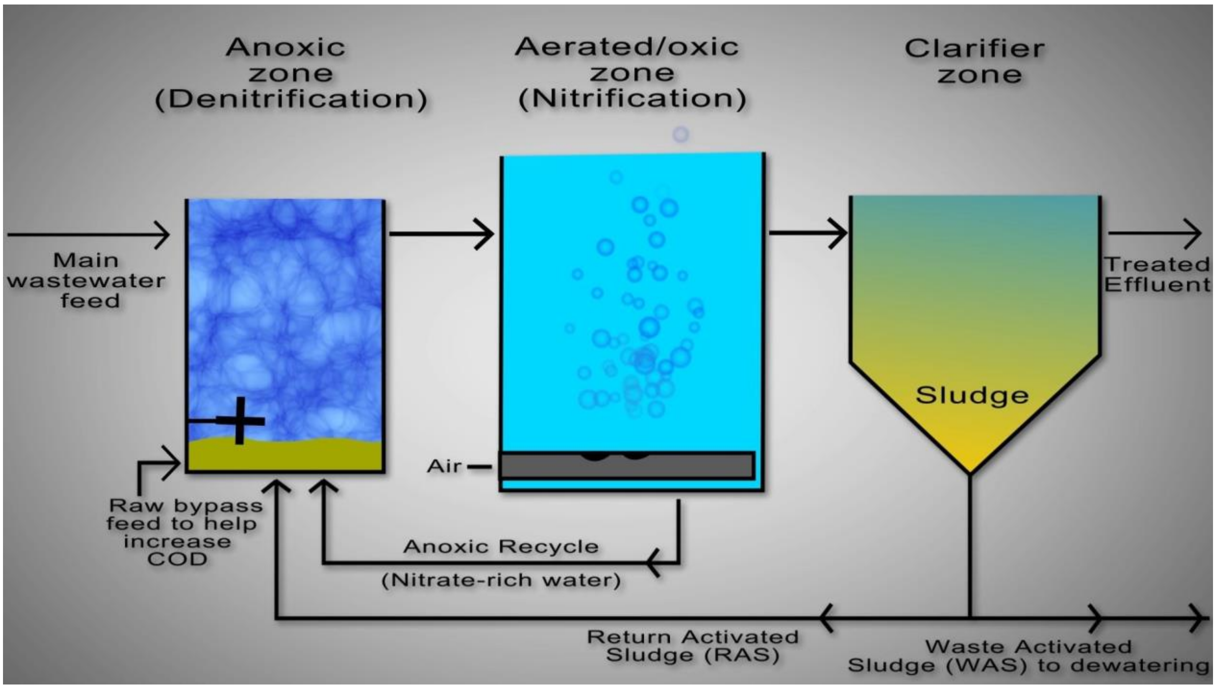
Table 13: Technologies for nitrogen removal

Technology	Process	Mode	Typical N removal	Status	In Australian meat plants
SBR	Bacterial	Intermittent	> 80%	Proven	> 5
BNR	Bacterial	Continuous	> 80%	Proven	> 4
Aerated Pond	Bacterial	Continuous	~ 65%	proven	1
Anaerobic Ammonium Removal (Anammox)	Bacterial	Continuous/ intermittent	> 80%	emerging	In trials
Dosed DAF	Chemical	Continuous	~ 50%	proven	many
Struvite	Crystallisation	Continuous	low	emerging	none

5.1.2 Nitrogen removal using activated sludge treatment

Nitrogen removal systems typically use activated sludge treatment processes where a mixture of bacteria and other microorganisms grow as settleable "flocs", often termed Mixed Liquor Suspended Solids (MLSS). During treatment, the flocs are suspended in the treatment basin by mixing, using either air bubbles from specialist air diffuser systems, or by mechanical "aerators". At the end of the process, the mixing is turned off and the flocs settle leaving a high quality clarified liquid. Figure 3 provides a diagram of a simple activated sludge process.

Figure 3: Simple activated sludge process diagram



For terms see Section 5.1.2.1.

The bacterial flocs (or sludge) are kept at high concentrations in the basin by recycling the sludge (termed Return Activated Sludge or RAS in continuous systems). However, treatment of the rich meat processing wastewater usually results in excess sludge being produced. This sludge (Waste Activated

Sludge or WAS) is removed and dewatered for disposal. Although aerobic bacteria are the most dominant microorganisms other anaerobic nitrifying bacteria and higher organisms can be present that can enable the process to be modified or adapted for biological nitrogen removal.

An Activated Sludge (AS) BNR process achieves nitrogen removal in a two-step process. The nitrogen cycle is shown in Figure 4.

Step 1: Nitrification - a multi-step reaction with the most prominent steps being

- Ammonia is converted to nitrite (NO_2^-) by ammonia oxidising bacteria (AOB);
- Nitrite is further oxidised to nitrate (NO_3^-) by nitrite oxidising bacteria (NOB);

  Nitrification only changes the form of dissolved nitrogen in the wastewater, but it is an essential first step for removal.

Step 2: Denitrification - nitrate is reduced to dinitrogen gas (N_2) by denitrifying bacteria. The N_2 escapes the wastewater into the atmosphere. This step removes the nitrogen from the wastewater.

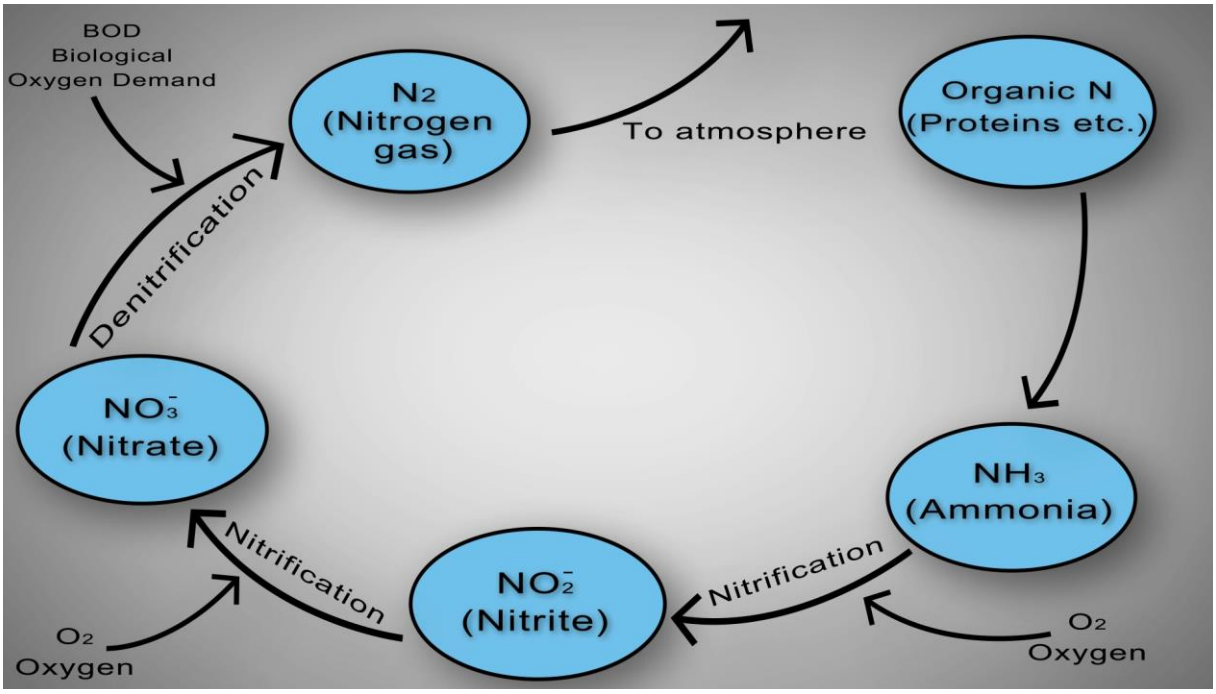


Figure 4: Nitrogen cycle

The environment required for each step is radically different (see Table 14), although in certain circumstances both steps may occur through a process termed Simultaneous Nitrification Denitrification (SND). The two types of AS BNR system provide these two different environments in different ways:

- In Continuous BNR processes, nitrification and denitrification are performed in different parts of the reactor. An example is the Biolac process where although the denitrification zones are not separated by walls from the nitrification zones, there are distinct areas allocated for each reaction (See photo). This requires the constant circulation of flow between zones to complete the reaction.

Image 18: Continuous Activated Sludge system
Biolac, Teys, Beenleigh

- In SBR BNR processes, nitrification and denitrification occur in the same reactor space, but at different times in the cycle. For example, the aeration system turns on for the nitrification part of the cycle, then switches off during the denitrification period. This saves the need for pumping large volumes of liquid around or for separate structures such as clarifiers.

Image 19: Sequencing Batch Reactors
JBS, Dinmore

Provided the appropriate environment is present, the relevant bacterial will perform the reactions needed to reduce nitrogen levels.

Table 14: Environment needed for each of the nitrogen removal steps

Environmental parameter	Nitrification	Denitrification
COD or BOD level	Kept as low as possible	High levels of readily biodegradable COD required
Aeration	Requires oxygen supply	Oxygen is absent
Initial Nitrogen form	Ammonia	Nitrate
pH trend	Acid produced	Alkalinity produced
Final nitrogen form	nitrate	N_2 gas

5.1.2.1 Continuous Activated Sludge (AS) BNR systems

Figure 3 illustrates the main components of a modern continuous AS BNR plant. These are:

1. **Anoxic (denitrification) basin or zone**
   This basin, or zone of the plant is where conditions are established to promote denitrification. It continually receives several streams:
   - **Main feed**
     Ammonia-rich wastewater from the upstream CAL or anaerobic pond. This is a large volume stream containing the bulk of the new nitrogen load to the system. Unfortunately, the COD content of this stream is usually insufficient to provide all the COD needed for the denitrifying bacteria.
   - **Raw bypass feed**
     Most meat processing AS BNR systems require additional COD to fuel the denitrification reaction to completion. This can be done by adding an external carbon source (such as ethanol or methanol), but this is expensive. Most systems divert a portion of the raw primary-treated wastewater to the anoxic basin to supply the carbon needed. Since this stream bypasses the upstream CAL, it is often termed the raw bypass. For some systems, this can be as high as 25% of the total wastewater flow.
   - **Return Activated Sludge (RAS)**
     RAS is usually pumped out of the thickened sludge at the base of the clarifier. The role of the RAS stream is to recycle bacterial flocs back to the reactor basins to maintain high bacterial concentrations (called Mixed Liquor Suspended Solids, MLSS). This ensures fast rates of treatment
   - **Nitrate-rich recycle stream**
     Denitrifying bacteria require nitrate. This is not present in the raw wastewater feed and must be supplied as a recycle from the downstream aerated basin. In the Biolac process, the upstream aerated zone provides the nitrate-rich water for the downstream anoxic zone (so there is no separate recycle stream).

The basin is usually mixed in a manner to minimise the presence of oxygen, for example with submerged mixers. In the anoxic basin, denitrifying bacteria catalyse the conversion of nitrate to nitrogen gas and consume COD in the process. The loss of nitrogen gas to the atmosphere removes it from the wastewater.

Image 20: Anoxic zone (left) and aerated zone (right)
Biolac, Teys, Beenleigh

2. **Aerated basin or zone**
The wastewater continually flows out of the anoxic basin or zone into the aerated basin or zone. This part of the AS system is continuously aerated to maintain a high dissolved oxygen (DO) concentration. This supports two important reactions:
   - **COD removal**
   Heterotrophic bacteria consume any remaining biodegradable COD aerobically to form new cells and CO_2. These excess cells must be continually removed as WAS (Waste Activated Sludge) to maintain a steady MLSS level in the system.
   - **Nitrification**
   The incoming raw wastewater feed from the anoxic basin/zone contains high concentrations of ammonia. In the presence of the high DO and low COD levels, nitrifying bacteria in the flocs convert the ammonia to nitrate. This produces excess nitrifying bacteria cells which are also removed in the WAS. The acid released by the nitrification process is neutralised by the alkalinity generated by both the upstream CAL or anaerobic pond (if there is one) and denitrification.

   The contents of the aerated basin flow continually into the clarifier.

3. **Clarifier**
In the clarifier, the bacterial floc settles out of the water column in the still environment provided. The treated effluent overflows the clarifier usually through some kind of weir system and should contain low TSS levels (typically less than 20 - 50 mg/L). The settled sludge is pumped out of the base of the clarifier and split into the:
   - RAS stream which is recycled as described above
   - WAS stream which is pumped to the dewatering plant for disposal

Image 21: Clarifier
Biolac, Teys, Beenleigh

4. **Dewatering device**
In red meat processing WWTP, this is typically a belt filter press or decanter centrifuge. The WAS stream is injected with a suitable polymer which promotes large, stable flocs for dewatering. The mixture is pumped to the dewatering device which removes large quantities of water from it and generates a dewatered WAS (DWAS) cake. Ideally this cake should have a moisture content between 12 – 20% DS and have a consistency somewhat like wet cardboard. The filtrate is returned to the head of the AS BNR system. The DWAS is disposed to an appropriate waste management facility such as composting or landfill.

Note that the Biolac process used in several Australian meat plants, does not physically separate anoxic and aerated zones in tanks, but alternates these zones along the Biolac basin. Anoxic zones are created by turning off air to selected aeration headers, whereas in aerated zones the aeration remains on.

Table 15 contrasts the positive and negatives of continuous activated sludge systems.

Table 15: Properties of continuous activated sludge systems

Positives	Negatives
Low maintenance	Not very flexible (to changes in wastewater volume or quality)
Relatively robust	High operating & capital costs
Relatively easy to operate	Large amounts of sludge production
High effluent quality able to meet current and anticipated future discharge requirements	Large volumes of wastewater are circulated.
	Skilled operators are required to operate system

5.1.2.2 Sequencing Batch Reactor (SBR) BNR Plants

Sequencing batch reactors (SBR) undertake the activated sludge process in batches. Rather than performing the anoxic, aerated and settling processes in different specialised tanks each with their own equipment as in continuous NR plants, all stages in the SBR are performed in one tank or pond, but at different times. Note that the same biological processes are used. Only the reactor is different. Table 16 summarises the benefits and challenges of SBRs.

Table 16: Properties of Sequencing Batch Reactors

Positives	Negatives
High degree of operational flexibility (to changes in wastewater volume or quality)	Higher level of control required compared to continuous BNR
Lower capital cost than continuous BNR since expensive clarifiers are not required.	Batch operation means that upstream storage required if only 1 SBR
High degree of automation	Requires knowledgeable and experienced operators
Small footprint	Equalization prior to discharge may be required due to discontinuous discharge.
High effluent quality able to meet current and anticipated future discharge requirements	Large biological sludge production

The key to nitrogen removal in an SBR is the time-based control strategy employed. This strategy is built around a "cycle" consisting of a number of "phases" such as aerate & fill, anoxic, settling and decant etc. (Figure 5). Each of these phases establishes the environment conducive to the process required by controlling the entry/exit of streams and operation of equipment. This is automated using PLC control. Once the SBR has completed a cycle, the cycle clock resets to zero and the SBR repeats the cycle with a new batch of wastewater. A close analogy to the SBR is the domestic dishwasher (e.g. one batch of dirty plates per cycle with time-separated rinse, wash & dry phases).

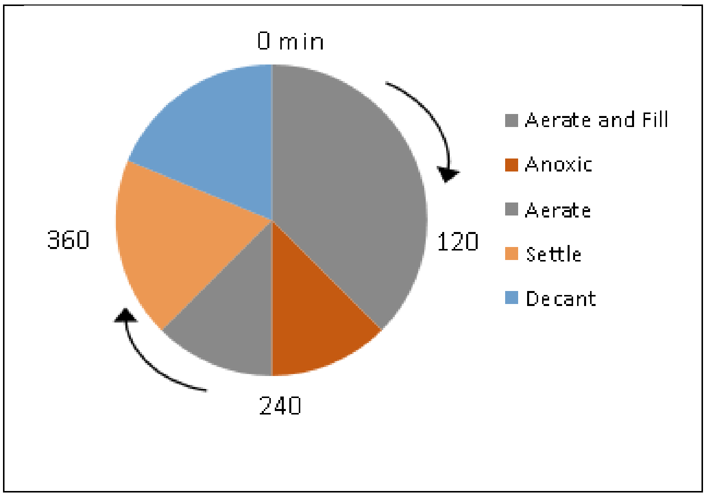


Figure 5: SBR Cycle with 5 phases totalling 480 minutes


Image 22 Aerated phase
SBR, JBS, Dinmore


Image 23: Anoxic phase, decanter wier to the left
SBR, JBS, Dinmore

Since the SBR operates using one tank, it does not need:

- An expensive clarifier
- RAS and recycle streams which usually require large pump and pipe circuits

However, SBRs require:

- A decanter mechanism which operates during the decant cycle to remove clarified water
- Upstream storage to hold wastewater during phases when wastewater may not enter the SBR. Typically, an upstream CAL or anaerobic pond is used for this, or twin SBRs are used in parallel.

Waste Activated Sludge (WAS) must still be removed from the SBR – this is usually achieved using a WAS pump to withdraw MLSS from the SBR during aerate & fill phase. The WAS is dewatered in exactly the same manner as for continuous BNR plants.

5.1.2.3 Anaerobic Ammonium Removal (AAR) – emerging technology

Traditional activated sludge BNR systems (as described above) remove nitrogen at high power and operating costs and have additional environmental impacts including high sludge production and emission of greenhouse gas including N_2O that contribute to global warming. Anaerobic ammonium-oxidizing (anammox) bacteria convert ammonium and nitrite directly to dinitrogen gas (N_2) under anoxic conditions. As the cost of conventional ammonium removal via nitrification-denitrification is mainly associated with aeration-costs significant power and operational savings can be made.

Table 17 contrasts the positive and negatives of AAR technology. Numerous full scale AAR plants have been installed in Europe and China mainly on sewage treatment side streams (from anaerobic digestors). Due to biosecurity restrictions on importation of AAR bacteria into Australia, they must be grown using indigenous AAR bacteria. Since their growth rate is very slow, this has severely restricted application of AAR processes in Australia and it will be only in the next 2-5 years that full-scale plants may emerge.

Table 17: Properties of Anaerobic Ammonium Removal technology

Benefits	Challenges
Reduced power consumption compared to conventional BNR - AAR requires 60% less aeration	Very low growth rate of AAR bacteria coupled with biosecurity restrictions mean full scale demonstration in Australia 2-5 years away
Reduced overall operational cost compared to conventional nitrification/denitrification	Inhibited by excess sulphides and TSS
Zero BOD or COD requirement	Requires careful control of nitrate oxidising bacteria
Low sludge production	Doesn't achieve compete nitrogen removal
CO_2 emission can be reduced by because the process itself consumes CO_2	Anammox bacteria are sensitive to environmental factors such as elevated oxygen, nitrite and phosphate concentrations.
Nitrous oxide (N_2O) that formed during conventional denitrification is not emitted	Not proven on meat processing wastewater
Small plant foot print	

5.1.3 Phosphorus removal technologies

Phosphorus removal has not been commonly applied in Australian meat processing plants discharging to land or surface waters in Australia except in a few relatively rare instances. For plants discharging to sewer, phosphorus removal is achieved as a byproduct of the chemicals added to the DAF to reduce COD, TSS and oil & grease to levels acceptable for discharge.

Table 18 summarises the technologies most commonly used for phosphorus removal in Australian meat processing plants. The dominant proven technology is chemical precipitation of phosphorus. This is usually performed in activated sludge basins to minimise the cost associated with sludge handling. As mentioned, it is routinely applied in chemically dosed DAFs treating effluent for sewer discharge.

Table 18: Technologies for phosphorus removal

Technology	Process	Typical P removal	Status	In Australian meat plants
Chemical precipitation	Chemical	< 5- 10 mg/L	proven	2-3
Dosed DAF	Chemical	< 5- 10 mg/L	proven	many

Bio P activated sludge	Bacterial	< 1 – 2 mg/L	difficult	1
Struvite	Crystallisation	> 10 mg/L	emerging	none

5.1.3.1 Chemical precipitation – in BNR Basins

Total phosphorus (TP) in meat processing wastewater is usually a mix of inorganic phosphate (PO_4^{3-}) and organic phosphorus associated with proteins, fats etc. After anaerobic treatment, virtually all the TP is converted to the inorganic phosphate form (often called "reactive phosphorus" by labs). This makes it suitable for precipitation by reaction with precipitants typically trivalent metals salt forms of aluminium (e.g. alum = aluminium sulphate) or iron (e.g. ferric chloride).

Table 19 outlines some of the considerations for this option. It is important to realise that some chemical precipitants require supplementary alkalinity dosing (lime, MHL or similar) to maintain pH in the BNR basin and in turn this increases the non-volatile component of the floc and overall cost.

Table 19: Considerations for phosphorus precipitation in BNR basins

Benefits	Challenges
Greatly reduced capital & operating costs compared to stand alone P precipitation plant	Need to watch non-volatile solids fraction in biological floc otherwise BNR treatment suffers
Use existing BNR dewatering equipment	Need good mixing in BNR basin
Inorganic precipitant in activated sludge flocs improve dewaterability	Check precipitation does not affect final WAS disposal options
Small footprint	Limits MLSS levels

5.1.3.2 Chemical precipitation – standalone plants

Phosphorus can be precipitated in standalone equipment which comprises:

- Dosing chemical storage & makeup
- Dosing pumps
- Flash mix tank
- Clarifier to separate precipitated solid P sludge from treated effluent
- Dewatering device for the sludge

This approach is rare in Australian meat plants but may become more common as regulatory enforcement of lower phosphorus limits increases and/or currently irrigated land becomes saturated with phosphorus. The precipitation chemistry is similar to that for BNR basins.

A major factor to consider is the disposal of the precipitated inorganic phosphorus sludge. In some cases, this may be a regulated waste and be expensive to dispose of.

Struvite (magnesium ammonium phosphate) can be used to treat biologically high strength wastewater high in phosphate to create a "green" phosphate fertilizer and calcium to precipitate hydroxyapatite. Both of these approaches result in phosphate that is more available for plant growth.

5.1.3.3 Biological phosphorus removal

In activated sludge BNR plants whether continuous or SBR types, phosphorus can be removed by its uptake into certain phosphorus accumulating bacteria. The Bio-P technology requires a two-step approach involving:

- An initial anaerobic reactor or phase in which there are very high levels of readily biodegradable carbon and low nitrate/oxygen levels;
- A subsequent aerobic reactor or phase in which the phosphorus is taken up into the cells to very high levels. The P-rich bacteria are then removed from the BNR process via the WAS stream.

This technology is now widely employed in sewage plants across the world including Australia.

Biological phosphorus removal (Bio-P) is rare in meat processing plants due to the difficulty associated with achieving suitably high readily biodegradable carbon levels in a cost-effective manner and maintaining low nitrate levels in the anaerobic reactor/phase. This is due to the much higher nutrient levels encountered in meat plants compared to sewage facilities. Nevertheless, it was demonstrated at large pilot scale during a MLA-funded research project in the mid-2000's.

The dewatered biological sludge containing the excess phosphate is disposed of by composting, land rehabilitation or another low grade uses.

5.1.3.4 Struvite

The struvite molecule consists of one each of magnesium, ammonia and phosphate in a crystalline form with 6 associated water molecules. It is produced by a crystallisation process in which the pH is manipulated simultaneously with magnesium addition. The product is a stable, non-odorous slow release fertiliser product.

Proprietary technology exists which is proven at large scale, but has yet to gain a foothold in meat plants.

5.2 Legislative and regulatory requirements

Direct regulatory requirements concerning nutrient removal will be stated in the facility's environmental protection licence, permit or approval which is issued by State Government.

The main focus is usually on minimising the risk of odour especially from BNR systems, overflow control (bunding for DAFs and chemical precipitation plant) and the appropriate off-site transport and disposal of the dewatered waste solids.

5.3 Commissioning Activated Sludge BNR Systems

Activated sludge BNR systems are complex to commission and this is generally left to specialist teams. Commissioning typically involves:

- Testing electrical, control and mechanical equipment and resolving issues prior to introducing wastewater. This avoids severe offensive odour events if a system fails to function properly;
- Training operating personnel

- Introducing wastewater and sludge under controlled conditions to ensure COD removal and the establishment of a good settling sludge
- Establishing biological nitrogen removal
- Establishing good operation of the dewatering system including polymer optimisation

This process may take at least one – two months to settle down. It is important that during this period, any sort of shock load is avoided. Shocks (sudden significant increases in pollutants or flow) may be of several types:

- Organic: from events such as blood, stickwater or tallow spills, introduction of excessive raw feed or large scale cleaning of heavy manure loads from animal lairages
- Hydraulic: due to high flow events such as rainfall, excess recycle usage etc.
- Saline: due to events, such as washing out hide or skin sheds, discharge of demineralisation liquors, etc.
- Solids: from many of the above or bypassing or poor operation of paunch solids recovery devices (screens, screw presses)

Care is needed to ensure that any preceding anaerobic pond or CAL is also performing good COD removal otherwise it may be very difficult to commission the BNR system.

The best signs that the BNR system is well established and capable of processing the design load and flow are as follows:

- There is a good settling bacterial floc in the basin and final TSS levels in the treated effluent are low on average (< 50 mg/L)
- COD or BOD removal is within 10% of design removal and stable from week to week. The design removal will vary from system to system due to unique aspects of each facility, but typical final BOD levels should be less than 20 mg/L
- Dissolved Oxygen set points are achieved in the aerated basin (continuous BNR), or during the aeration & fill phase (SBR BNR)
- Design nitrogen removal is obtained without significant pH changes;
- There is no unpleasant smell
- The dewatered WAS has a solids content higher than 12% by weight and the consistency of wet cardboard off the dewatering device

5.4 Operating & maintaining BNR Systems

5.4.1 Recommended operator responsibilities

Activated sludge BNR systems require daily operator attention. The time is generally spent:

- Monitoring performance - Activated sludge BNR systems are extremely responsive due to their relatively short hydraulic retention times and their high bacterial concentrations (MLSS) which are typically of the order of 4 – 6,000 mg/L. Consequently, it is important that their performance is monitored daily, especially where the treated effluent must meet stringent quality limits due to river discharge or high quality reuse (e.g. recycle into membrane reuse systems).
- Operating the dewatering devices – These devices need to operate several times a week to remove and dewater the WAS from the system. Sludge dewatering behaviour is complex and affected by

many factors including pH, weather, sludge settling behaviour and many more. Consequently, some time is needed to ensure that the right dewatering conditions and polymer addition levels are established each time the device is operated. As the operator becomes familiar with the system, the time needed reduces.

It is critical that any changes to system operation are made in a considered manner and in accordance with the designer's operating parameters. This is because impacts from some changes may take up to a month to surface (especially where sludge age is long). appropriate times in the cycle.

Table 20 lists common responsibilities for continuous activated sludge BNR systems. Table 21 provides the same for SBR systems. Note that for the SBR systems, attendance will be needed at appropriate times in the cycle.

Table 20: Operator responsibilities for Continuous AS BNR Systems

Tasks	Important Operator Responsibilities
Maintain MLSS Levels in the system	• Daily measure the MLSS level (see Monitoring). • Daily run the dewatering device to dewater the WAS generated by the day's production. This is a major component of work since it requires checking polymer level, starting the device, ensuring the DWAS is of good consistency and dry solids and checking the filling of the DWAS transport. • Clean dewatering area after completion. • Check RAS pumps are operating properly. • Recording the WAS flow dewatered (needed to estimate sludge age). • Calculate sludge age.
Maintain aeration system	• Ensure aeration system is operating appropriately and receives required maintenance (e.g. diffuser cleaning and/or replacement). • Check DO levels in aeration & anoxic basins to ensure they are at design settings. • Warn supervisor if DO can't be maintained.
Monitor treatment performance	• Collect samples required to monitor critical parameters such as COD, TSS, ammonia, nitrite, nitrate, phosphate and pH. • If on-line sensors are available to monitor these parameters, check regularly (at least daily) to monitor levels. Clean & calibrate sensors as required; • If ammonia levels in treated effluent increase, discuss with supervisor. • If nitrite or nitrate levels in treated effluent increase, discuss with supervisor.
Monitor sludge settling	• Sample & test settleability of sludge from aeration basin at least daily (see Monitoring). Record result preferably in spreadsheet. • If settleability changes markedly, notify supervisor immediately; • Check for increasing levels of scum, foam, mousse (looks like fat or pavlova mixture) or crust on the basins. This may be a sign of bacterial bulking. Inform the supervisor to determine the course of action; • Failure of sludge to settle is a serious problem and urgent action is needed. It usually leads to increased TSS in the final effluent.
Routine Checks	• Ensure inlet & outlet weirs, pipes & pumps are not blocked. • Check that the clarifier overflow is high quality & the sludge blanket is well below the overflow weirs. • Check any chemicals required (e.g. for P dosing) are available.

Table 21: Operator responsibilities for SBR BNR Systems

Tasks	Important Operator Responsibilities
Maintain MLSS Levels in the system	• Daily measure the MLSS level (see Monitoring). • Daily run the dewatering device to dewater the WAS generated by the day's production. This is a major component of work since it requires checking polymer level, starting the device, ensuring the DWAS is of good consistency and dry solids and checking the filling of the DWAS transport. • Clean dewatering area after completion. • Check raw feed pumps are operating properly and that anaerobic main stream control valve operates correctly. • Recording the WAS flow dewatered (needed to estimate sludge age). • Calculate sludge age.
Maintain aeration system	• Ensure aeration system is operating appropriately and receives required maintenance (e.g. diffuser cleaning and/or replacement). • Check DO levels during aeration & anoxic phases to ensure they are at design settings. • Warn supervisor if DO can't be maintained.
Monitor treatment performance	• Collect samples required to monitor critical parameters such as COD, TSS, ammonia, nitrite, nitrate, phosphate and pH. • If on-line sensors are available to monitor these parameters, check regularly (at least daily) to monitor levels. Clean & calibrate sensors as required; • If ammonia levels in treated effluent increase, discuss with supervisor. • If nitrite or nitrate levels in treated effluent increase, discuss with supervisor.
Monitor sludge settling	• Sample & test settleability of sludge from aeration basin at least daily (see Monitoring). Record result preferably in spreadsheet. • If settleability changes markedly, notify supervisor immediately; • Check for increasing levels of scum, foam, mousse (looks like fat or pavlova mixture) or crust on the basins. This may be a sign of bacterial bulking. Inform the supervisor to determine the course of action; • Failure of sludge to settle is a serious problem and urgent action is needed. It usually leads to increased TSS in the final effluent.
Routine Checks	• Ensure inlet & outlet (decanter operation), pipes & pumps are not blocked. • Check that the decant overflow is high quality & the sludge blanket is well below the decanter weir during the decant phase. • Check any chemicals required (e.g. for P dosing) are available.

Table 22: Recommended monitoring for Activated Sludge BNR & SBR systems

Parameter	Sample point	Comments
MLSS concentration (mg/L) – the most important operating parameter.	Mixed contents of basin; During aerate & fill phase (SBR)	Measure daily. One of the most critical tests. Defines the need for dewatering to maintain the operating MLSS and sludge age setpoint.
pH, temperature & electrical conductivity	Mixed contents of basin; During aerate & fill phase (SBR)	Measure daily. Usually use a portable instrument.
Dissolved oxygen concentration (mg/L)	Mixed contents of basin; During aerate & fill phase (SBR)	Measure daily. Usually use a portable instrument. This provides a check on the on-line DO sensors.
COD, TSS, pH, TN, NH_3-N, NO_x-N and TP	Treated effluent	As required. Check system performance. These may be monitored in-house using modern spectrophotometers with digestion block, or externally.
Sludge settleability	Mixed contents of basin; During aerate & fill phase (SBR)	Measure daily using settleometer or measuring cylinder. Record tests as interface of sludge & clear liquid (ml/L). Critical test for identifying problems with sludge settling.
WAS flow to dewatering device	Installed flowmeter	Essential for calculating sludge age
Raw feed flow to BNR	Installed flowmeter	Essential for balancing carbon supply for denitrification
Total flow to BNR	Installed flowmeter	Essential for ensuring hydraulic retention time is appropriate.

These results must be recorded, preferably in a spreadsheet for calculation of important operating parameters. These data are essential for troubleshooting.

5.4.2 Supervisor/management responsibilities

A skilled operator is valuable for keeping an activated sludge BNR system operating well and the constant feedback from monitoring results should assist in building their experience and confidence in operating the system. The key recommended management responsibilities include:

- Review monitoring data to observe trends with time. The best means of catching problems before they cause non-compliance with final effluent quality is to watch trends with time for:
  - Influent COD and nitrogen load (daily flow x influent concentrations)
  - DO levels during aeration, especially during summer
  - pH trends (heavily impacted by nitrogen reactions)
  - Sludge settling behaviour (if you can't settle the sludge, the final quality of the treated effluent becomes seriously compromised and it can be hard to maintain MLSS targets)
  - Final effluent quality with time
- Ensure maintenance is performed and regular calibration of sensors (especially DO) is performed.
- Anticipate impacts of sustained increases or decreases in production on the operation of BNR systems. Where needed, obtain specialist advice on these impacts.

6 BIOGAS CAPTURE SYSTEMS

6.1 Overview of biogas capture systems

6.1.1 How they work

Biogas is the product of anaerobic biological breakdown of organic substances. It is produced by any anaerobic technology when conditions are suitable for methane production and can be generated by bacteria from organic waste solids (in digesters) or from wastewater containing organic material.

Anaerobic ponds or lagoons are a common treatment step of wastewater produced from the meat industry. The technology is simple and inexpensive to operate while significantly reducing the wastewater organic loading.

The by product, biogas, is both a valuable fuel and a greenhouse gas (contributing towards carbon emissions). Captured biogas can be used to fuel a boiler or for co-generator. The burning of the biogas also significantly reduces carbon emissions. Hence, the covering of the anaerobic ponds has recently become popular.

6.1.2 Typical biogas capture system

A standard layout showing the main components for the biogas capture system for a CAL is presented in Figure 6.

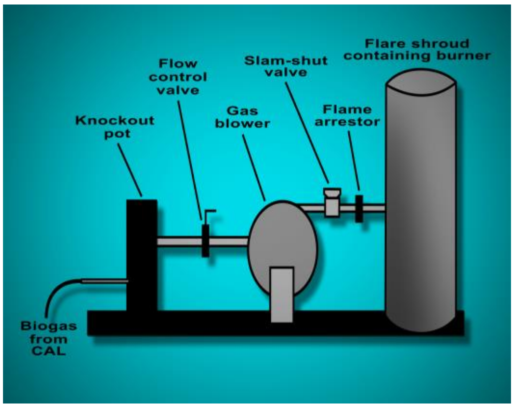


Figure 6: Typical layout of a biogas delivery system and flare

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 flares 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.

Image 24: Enclosed Biogas Flare
JBS, Dinmore

- **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 6.

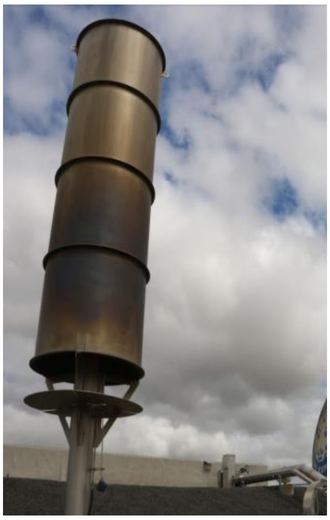


Image 25: Candlestick flare
NB Foods, Oakey

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.

6.1.3 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 23 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 23: 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	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.

6.2 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

6.2.1 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.

6.2.1.1 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.

6.2.2 Greenhouse gas emissions

As noted in Table 23, 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 into the atmosphere or combusted for on-site energy generation, 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.

6.3 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.

6.3.1 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.

6.4 Operating and maintaining biogas capture systems

6.4.1 Operator responsibilities

6.4.1.1 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.

6.4.1.2 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.

6.5 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

7 INFORMATION FOR PERSONNEL TRAINING WASTEWATER OPERATORS AND MANAGERS

7.1 Why training for wastewater 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.

7.2 Accredited training available for waste water operators and managers

7.2.1 Certificates

NWP30315 - Certificate III in Water Industry Treatment
The nationally recognised qualification reflects skills required to monitor, operate and control treatment processes within a wastewater treatment plant. 11 units of competency are required comprising of 2 core units and 9 elective units including:

- NWPGEN001 Apply the risk management principles of the water industry standards, guidelines and legislation (core)
- NWPGEN004 Assess, implement and report environmental procedures (core)
- BSBWHS302 Apply knowledge of WHS legislation in the workplace
- NWPGEN008 Sample and test wastewater
- NWPTRT033 Operate and control DAF processes
- NWPTRT041 Operate and control granular media filters
- NWPTRT043 Operate and control membrane filters
- NWPTRT054 Operate and control chloramination processes
- NWPTRT062 Operate and control reclaimed water irrigation
- NWPTRT072 Operate and control odour removal processes
- NWPTRT081 Operate and control activated sludge processes
- NWPTRT082 Operate and control nutrient removal processes
- NWPTRT083 Operate and control aerobic bioreactor processes
- NWPTRT091 Operate and control solids handling processes
- NWPTRT092 Operate and control digestion processes
- NWPTRT094 Operate and control incineration processes
- NWPTRT101 Operate and control lagoon processes
- NWPGEN009 Perform complex testing
- NWPSOU001 Respond to blue green algae outbreaks

NWP40615 - Certificate IV in Water Industry Treatment
The general qualification covers the skills for those who have supervisory responsibility and require a broad range of skills required to assess and improve the processes within a drinking water treatment plant. 10 units of competency are required comprising of 2 core units and 8 elective units including:

- NWPGEN002 Ensure compliance with water industry standards guidelines and legislation (Core)
- NWPGEN005 Coordinate and monitor the application of environmental plans and procedures (Core)
- BSBWHS404 Contribute to WHS hazard identification, risk assessment and risk control
- NWPTRT051 Assess and improve treatment for pathogen removal
- NWPTRT084 Assess and improve activated sludge and nutrient removal processes
- NWPTRT085 Assess and improve wastewater processes to control microbial impacts
- NWPTRT083 Operate and control aerobic bioreactor processes
- WPTRT011 Assess and optimise chemical dosing process
- NWPTRT032 Assess and improve sedimentation systems
- NWPTRT042 Assess and improve granular media filters
- NWPTRT045 Assess and improve desalination processes
- NWPGEN010 Contribute to the continuous improvement of quality systems
- NWPGEN013 Apply principles of chemistry to water systems and processes

NWP30107 - Certificate III in Water Industry Operations
This qualification allows for the attainment of general competencies in water industry operations or specialisation in networks, source, irrigation or treatment. 11 units of competency are required comprising of 2 core units and 9 elective units.

NWP40515 - Certificate IV in Water Industry Operations
The general qualification covers the skills for those who have supervisory responsibility and require a broad range of skills in water industry operations or specialisation in networks, source, hydrography, irrigation or trade waste. 11 units of competency are required comprising of 2 core units and 9 elective units.

7.2.2 Meat Processing Waste Water Operator Skills Sets

These skill set drawn from the Australian Meat Industry Training Package has been developed to address the need to offer formal training for people charged with operating wastewater treatment plants and related managing environmental issues.

AMPSS00057 Meat Processing Waste Water Operator Skill Set (Level 1)
This Skill Set describes the skills and knowledge to monitor the operation of wastewater plant and equipment, including the collection and testing of water samples. This Skills Set contains the following Units of Competency:

- AMPCOR204 Follow safe work policies and procedures
- AMPCOR205 Communicate in the workplace
- AMPX208 Apply environmentally sustainable work practices
- NWP208A Perform basic wastewater tests
- NWP262A Monitor and report wastewater treatment processes
- NWP263A Operate and maintain wastewater treatment plant and equipment

AMPSS00058 Meat Processing Waste Water Irrigation Skill Set (Level 2)
This Skill Set describes the skills and knowledge to operate and monitor meat processing wastewater treatment processes where the water is used for irrigation. This Skills Set contains the following Units of Competency:

- NWPTRT061 Operate and control wastewater processes
- NWPTRT062 Operate and control reclaimed water irrigation

AMPSS00059 Meat Processing Waste Water Non-Irrigation Skill Set (Level 2)
This Skill Set describes the skills and knowledge to undertake the treatment, collection and transfer of waste water in a meat processing plant. This Skills Set contains the following Units of Competency:

- NWPNET042 Monitor and operate wastewater collection and transfer systems
- NWPTRT052 Operate and control hypochlorite disinfection processes
- NWPTRT054 Operate and control chloramination processes
- NWPTRT061 Operate and control wastewater processes

AMPSS00060 Meat Processing Waste Water Environment Officer Skill Set (Level 3)
This Skill Set describes the skills and knowledge to monitor and control water and wastewater system assets in a meat processing enterprise. This Skills Set contains the following Units of Competency:

- AMPCOR206 Overview the meat industry
- AMPX410 Facilitate achievement of enterprise environmental policies and goals
- MSL954001 Obtain representative samples in accordance with sampling plan
- MSL973001 Perform basic tests
- MSMENV172 Identify and minimise environmental hazards
- NWPNET025 Coordinate and manage maintenance and repair of network assets

7.2.3 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.

- AMPCOR206 Overview the meat industry
- AMPX208 Apply environmentally sustainable work practices
- AMPCOR204 Follow safe work policies and procedures
- AMPCOR205 Communicate in the workplace
- MSMENV472 Implement and monitor environmentally sustainable work practices
- NWP706A Review and evaluate water and wastewater sustainability objectives
- NWPIRR024 Monitor and conduct maintenance on flow control and metering devices
- NWPNET045 Test and commission wastewater collection systems
- NWPNET042 Monitor and operate wastewater collection and transfer systems
- NWP262A Monitor and report wastewater treatment processes
- NWPTRT061 Operate and control wastewater processes
- NWP263A Operate and maintain wastewater treatment plant and equipment
- NWPTRT093 Assess and improve anaerobic digestion systems
- NWP357B Monitor, operate and control reverse osmosis and nano-filtration processes

- NWPTRT081 Operate and control activated sludge processes
- NWPTRT083 Operate and control aerobic bioreactor processes
- NWPTRT082 Operate and control nutrient removal processes
- NWPTRT062 Operate and control reclaimed water irrigation
- NWPNET025 Coordinate and manage maintenance and repair of network assets
- NWPTRT054 Operate and control chloramination processes
- AMPMGT508 Manage environmental impacts of meat processing operations
- AMPMGT506 Manage utilities and energy

7.3 Training Programs

- IWES, owned by the University of Queensland, offers a five-day course run annually on waste water treatment and management.

7.4 On site Mentoring

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.

7.5 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.
- AMPC (2015) Review of Removal of Fats, Oil and Greases from Effluents from Meat Processing Plants. prepared by Neil McPhail North Sydney.
  Current knowledge on the effect of FOG content of wastewater on the operation and performance of anaerobic treatment systems and techniques available to optimise operation and biogas production.
- AMPC (2017) Biogas Manual.
- MLA (2015) MLA case study: Waste to energy technology - Oakey Beef Exports. ABN 39 081 678 364
- MLA (2013) Design and Optimisation of a Purpose Built Covered Anaerobic Lagoon Stage 1. Project P.PIP.0293, prepared by Geolyse Pty Ltd and Colley Consulting. North Sydney
- MLA (2012) Demonstration of Covered Anaerobic Pond Technology, Project P.PIP.0290 prepared by Drs. Bronwen Butler and Michael Johns. North Sydney.
- Several useful reports are imminent from AMPC/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://off-farm.mla.com.au/Project-outcomes/Environment/Environmental-best-practice-guidelines-for-the-red-meat-processing-industry
- Eco-Efficiency Manual for Meat Processing - http://off-farm.mla.com.au/Project-outcomes/Environment/Eco-efficiency-manual-for-meat-processing
- Red Meat Processing Industry Energy Efficiency Manual - http://off-farm.mla.com.au/Project-outcomes/Environment/Red-meat-industry-energy-efficiency-manual

Other industry research:

- RIRDC (2013) Methane Recovery and Use at a Meat Processing Facility King Island. Project No. PRJ-005673, prepared by Troy White and Drs Michael Johns and Bronwen Butler.
  Report discusses the design, start-up and normal operation of a CAL
- 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
- SIWA (2005). Field procedures handbook for the operation of landfill biogas systems. Prepared by Working Group for Sanitary Landfills, International Solid Waste Association, Copenhagen.
  A 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.

APPENDICES

Appendix 1 - Definitions

Term	Definition
ANAEROBIC	Occurring in the absence of oxygen or not requiring oxygen to live. Anaerobic bacteria produce energy from food molecules without the presence of oxygen.
AEROBIC	Occurring in the presence of oxygen or requiring oxygen to live. Aerobic bacteria produce energy from food molecules in the presence of oxygen.
SLUDGE	Residual, semi-solid material that is produced as a by-product during wastewater treatment. Sludge from meat processing plants is typically composed of water, high levels of organic solids and fats, oils and greases.
BIOGAS	The gas resulting from anaerobic bacterial breakdown of organic material.
BIOGAS TRAIN	The equipment associated with the carriage, conditioning and preparation of biogas for burning in flares or other uses.
BOD	The amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period.
BOD_5	BOD is most commonly expressed in milligrams of oxygen consumed per litre of sample during 5 days of incubation at 20 °C. BOD_5 is often used to indicate the degree of organic pollution of water.
COD	Measurement of the oxygen required to oxidize soluble and particulate organic matter in water. Higher COD levels mean a greater amount of oxidizable organic material in the sample, which will reduce dissolved oxygen (DO) levels. A reduction in DO leads to anaerobic conditions, The COD test is often used as an alternate to BOD due to shorter length of testing time.
FLARE	An engineered unit which safely combusts biogas and air mixtures to destroy its methane content and odorous components.
PAUNCH	The abdominal contents of cattle that are removed at the time of slaughter.
PRIMARY WASTEWATER TREATMENT	Removal of course materials through screens and hydrocyclones, settleable organic and inorganic solids by sedimentation and the removal of materials that will float (scum) by skimming.
RENDERING	Any processing of whole animal fatty tissue into purified fats like lard or tallow. The rendering process simultaneously dries the material and separates the fat from the bone and protein.
SECONDARY WASTEWATER TREATMENT	Remove of biodegradable dissolved and colloidal organic matter using biological treatment processes.
TSS (TOTAL SUSPENDED SOLIDS)	Dry-weight of particles trapped by a filter. It is a water quality parameter used for example to assess the quality of wastewater after treatment in a wastewater treatment plant.
TERTIARY WASTEWATER TREATMENT	Advanced wastewater treatment to remove nitrogen, phosphorus, additional suspended solids, refractory organics, heavy metals and dissolved solids.
POTABLE WATER	water from any source that is meets national standards for human consumption.
RAW WATER	Water intake to a site from external sources (town, bore or other) and which excludes the addition of internally produced recycled water
RECYCLED WATER	water that has been used previously for whatever purpose and that has subsequently undergone treatment to potable quality.
ZONES	Potentially explosive areas are classified on the basis of zones according to the probability of the presence of a potentially explosive area. In Australia, the

Term	Definition
	appropriate standard is AS/NZ 60079.10:2009 *Explosive atmospheres – Classification of areas*.