



Beef cattle feedlots: waste management and utilisation

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Published by Meat & Livestock Australia Ltd | ABN 39 081 678 364 | September 2015
 | ISBN 9781741919172

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PREFACE

The beef feedlot industry has expanded greatly over the last two decades as the demand for high quality beef has increased in both local and export markets. At the same time, industry and the public have become more conscious of animal welfare, the environment and workplace health and safety. This manual deals with the management of the main wastes of the feedlot, namely manure and effluent.

CONTENTS OF SECTIONS

This manual is comprised of five sections describing best-practice guidelines for waste management.

1. Solid wastes

Wet dung and urine accumulate quickly on the feedlot pen. Pens have to be cleaned regularly for efficient cattle production and to minimise odour emissions. Thus the handling of manure becomes a major ongoing part of feedlot management. Mortalities and boiler ash are other solid wastes that may need to be managed.

2. Solid waste storage and processing

Harvested manure must be stored and processed. Stockpiling and composting manure reduces its bulk, improves handling and concentrates some nutrients. An area is also needed to store composting mortalities.

3. Management of odour, dust and flies

Odour is mainly the result of anaerobic breakdown of cattle manure. While good siting and feedlot design (particularly drainage) will minimise odour, good waste management is also essential. Dust from the pens, roads and manure stockpiling/composting area can be an issue under dry conditions. Flies are attracted to manure and need to be controlled at times.

4. Liquid wastes

Rainfall runoff from the pens is heavily loaded with nutrients. While this runoff can provide a good source of nutrients for plant growth, it needs to be safely stored until it can be utilised.

5. Utilisation of manure, compost and effluent

Feedlot manure, compost and effluent can be valuable sources of nutrients and organic matter for improving soil structure and fertility and crop or pasture production. Careful management is needed to gain the most benefit from their utilisation while protecting the environment and amenity.

APPENDICES

1. Standard operating procedures for waste management and utilisation

Suggested standard operating procedures for feedlot manure, compost and effluent management and utilisation.

2. Managing human exposure to contaminants

A brief overview of the main areas and activities in the feedlot where humans may be exposed to contaminants, including practical ways to minimise the risks of this potential exposure.

3. Duty of care: waste utilisation

Those utilising effluent, manure or compost must take reasonable and practical steps to prevent harm to the environment and nuisance to the general public.

4. Manure valuation pro forma

The economic value of manure can be assessed using the prices of commercial fertilisers and nutrient content of the manure.

5. Advances in waste treatment

Increasing environmental pressures and economic incentives for industries and enterprises to reduce greenhouse gas (GHG) emissions are driving interest in waste-to-energy projects.

6. NFAS Manual sample elements

To minimise the likelihood of a disease entering and spreading within the feedlot.

Bibliography

Glossary

BEEF CATTLE FEEDLOTS:
WASTE MANAGEMENT AND UTILISATION

1. Solid wastes

CONTENTS

The pen area must be cleaned regularly for odour and dust control, worker safety and efficient cattle performance.

Wet, muddy pens do not provide pleasant conditions for workers or cattle.

Manure interface layer over compacted gravel base

Introduction

The main waste product of a beef cattle feedlot is manure. To maintain good conditions for workers and cattle and to ensure sound environmental performance, manure must be removed from feedlot pens regularly. Some feedlots use bedding and this, along with small amounts of spoilt feed thrown into the pen during bunk cleaning, is removed with manure during pen cleaning. Thus manure handling becomes a major ongoing part of feedlot management. Spoilt silage and mill run, mortalities, and sometimes boiler ash, are other solid wastes that may also need to be managed.

Pen cleaning

Pens must be cleaned regularly to

- optimise cattle performance and welfare
- present animals for pre-slaughter inspection in a clean condition
- provide a safe work environment for staff (particularly pen riders)
- mimimise odour levels
- minimise dust during hot, dry conditions
- promote good pen drainage
- promote good integrity of the pen surface
- minimise costs of pen maintenance.

Frequent, regular pen cleaning reduces the average depth of manure over the pens, promoting more rapid pen drying. Odour emissions from wet feedlot manure can be 50–100 times higher than from dry manure and the odour is more offensive. Even a small area of wet manure, such as a pothole, can be a significant source of odour. Regular pen inspection allows low spots to be identified early and repaired.

Muddy, odorous conditions do not provide a pleasant, safe working environment for pen riders and others working within the feedlot.

Weight gains can be reduced by 30–40% and feed conversion rates increased by 20–35% when cattle are kept on deep manure. Wet, muddy conditions also adversely affect animal health, with increased incidence of foot problems such as foot abscesses.

The manure pad

As manure deposited on the floor of feedlot pens dries and is compacted by the action of cattle hooves, it typically forms layers. The lowest layer may be an ‘interface’ layer – a compacted, moist plastic mixture of manure and soil – which has low permeability and can reduce nutrient leaching through the feedlot pen. If there is no interface layer, the manure layer overlies the feedlot base directly as a moist and plastic layer, sometimes with a crust on the surface.

The thickness of the manure layer depends upon the manure deposition rate, the pen cleaning frequency, weather conditions and other factors. Under dry conditions, about 20 mm of manure accumulates across the pens after 25 days, gradually increasing to about 30 mm after 75 days and to around 35 mm after 100 days. When the dry compact manure pack is moistened by rainfall, it may double in depth.

Principles of pen cleaning

Feedlot pens should be cleaned at least every 13 weeks. Ideally, pen cleaning should occur when the manure is moist (but not wet). Moist manure is more easily removed in a good even cut for a smooth pen surface. However, pens should be cleaned regularly even when conditions are not ideal.

If a manure–soil interface layer will be retained, it is necessary to determine the depth of manure covering it. In moist manure, a screwdriver pushed into the pad will encounter increased resistance at the interface layer. The difference is less distinct if the manure is hard and dry and it may be necessary to dig into the pad to confirm the depth to interface.

The depth of manure and its moisture content will vary over the pen; for example, manure will accumulate and may be wetter under shade. During cleaning, care needs to be taken to prevent machinery from cutting too deep in different parts of the pen. If the manure is too hard, pen cleaning can be deferred until the manure moisture content increases.

Because of climatic conditions some feedlots do clean all manure from the feedlot floor. But this may include large amounts of soil or rock resulting in more material for processing, including manure screening. It may also increase pen maintenance needs and result in more wear and tear on manure handling equipment.

Attention to detail during pen cleaning is important to control odour since even small areas of wet manure can emit significant odour. Every time pens are cleaned, manure that has accumulated under fencelines, along the sides of feedbunks and water troughs and along aprons should also be removed. Cleaning under the bottom fenceline more frequently will also promote good pen drainage and fly control.

Manure can be temporarily mounded in the pens before stockpiling and composting, but never in drains or cattle alleys.

Temporary mounding of manure in the pen may increase management flexibility because

- decomposition reduces the mass of manure to be removed from the pen
- pens can be cleaned as required and more regularly
- the manure mound can be removed from the pen at a convenient time.

Mounds should be removed when conditions allow but also when

- they become too high for machinery to practically and safely drive over them
- they become a hazard to the welfare of cattle
- they begin to disintegrate under dry conditions
- manure haulage equipment becomes available.

To form stable mounds, the manure needs to be moist enough to be well compacted so that it can support the weight of cattle and also to exclude air. Mounds should be shaped so they shed runoff and located so as not to interfere with pen drainage. In unshaded pens, they should be situated in the centre of the pen with their long axis running down the slope. In pens with shade over the centre or top third of the pen, they should be located downslope of the shade structure.

A feedlot pen that has been cleaned to a smooth gravel base.

Manure being mounded with a box scraper.

Manure that accumulates under fence lines needs to be removed as it impedes drainage and provides a habitat for flies to breed.

Drains below the pens direct runoff to the holding pond and need to be kept clean.

Drains below the feedlot pens (which often also act as cattle lanes) are used to catch rainfall runoff and direct it to a holding pond generally via a sedimentation basin, tank or terrace. Drains need to be kept free of sediment build-up to maintain maximum flow capacity. Where drains are vegetated, the grass should be kept short by regular mowing.

Sedimentation facilities are designed to remove at least 50% of the settleable solids in the runoff, and should be cleaned out when they are dry to maintain removal capacity. This will reduce the amount of organic matter entering the holding pond and hence the potential odour emission rate. Weirs also need to be cleaned when deposited sediment is sufficiently dry. In wetter climates, having two sedimentation facilities in parallel allows one to be dried and cleaned while the other is in operation.

Manure entering the holding pond is broken down by microbial action, but some undegradable material is deposited as sludge on the floor of the pond. Holding ponds need to be cleaned when the required water storage capacity is compromised (e.g. less than 80% available), typically every 5 to 20 years depending on the initial size of the pond and the efficiency of the sedimentation system.

Pen cleaning equipment

Slider blade for removing manure from under fencelines, along aprons, around shade posts, and from drains and lanes

Equipment that can be used for pen cleaning includes

- *Tractor-drawn box scrapers* – box scrapers are widely used in medium to large feedlots in conjunction with wheel loaders. These scrapers provide good depth control, a smooth pen finish, a single manure removal and mounding operation and a fast rate of manure removal. However, they are less effective in wet conditions when an excavator may need to be used instead.
- *Wheel loaders* – wheel loaders are widely used in medium and large feedlots for removing mounded manure from the pen. While they can also be used to quickly clean the pens, they often produce a rough surface finish and may damage the interface layer. Buckets should be fitted with small teeth to minimise damage to the pen surface.
- *Excavators* – excavators can efficiently remove manure, particularly under wet conditions, but need to be used carefully as it can be difficult to achieve good depth control and a smooth finish. They are efficient at transferring mounded manure into trucks.
- *Skid-steer bobcats* – bobcats can be used to tidy up small areas.
- *Under-fence pushers* – mounted on tractors, front-end loaders or bobcats, under-fence pushers are commonly used for removing manure from under fencelines, around shade posts and water troughs; and manure and spilt feed from feed bunk aprons.
- *Slider blade* – mounted on a skid steer bobcat, the slider blade can be used in place of an under-fence pusher but can also clean drains and lanes.
- *Graders* – graders are suitable only for cleaning large pens; they provide good depth control and a smooth finish.

Wheel loader removing scraped and mounded manure from pen.

Manure collection and handling is a significant component of the feedlot budget. Different manure removal technologies offer different efficiencies in time and energy, but the most efficient systems may conflict with retaining an interface layer and maintaining an even pen surface.

For example, tractor-drawn box scrapers which provide good depth control and a smooth finish could have a capacity of 45–50 t/hr, compared to 80 t/hr for the wheel loaders which may produce a rough surface finish and damage the interface layer. The manure harvested with a wheel loader is likely to contain extra soil and rock, and this will increase the mass of material for transportation and processing.

Local climate conditions can also interfere with the retention of an interface layer and equipment used as illustrated in examples below.

CASE STUDIES

Cleaning in summer-dominant rainfall areas

The Queensland climate allows for year-round pen cleaning, manure mounding and retention of an interface layer. In a Queensland feedlot, pen cleaning was done every six to eight weeks. First, an under-fence pusher removed manure from under the fences, then a box scraper was used in a circular motion then diagonally to scrape the manure into a mound in the centre of the pen. The mound was retained for 12–18 months during which decomposition reduced its bulk by 20–30%. The manure was then collected by contractors using a front-end loader to break the mound and load the manure into trucks, resulting in little idling time. This simple system was time and cost efficient (Reeves 2007).

Cleaning in winter-dominant rainfall areas

Wet winters provide challenging conditions for pen cleaning. A New South Wales feedlot was cleaning its pens every eight to ten weeks. As the frequent wet conditions were not conducive to the formation of an interface layer, manure was harvested down to the gravel base using skid-steer equipment. An excavator cleaned the aprons and under fences, a front-end loader removed and mounded the manure and another front-end loader filled two trucks parked below the pens (Reeves 2007).

Manure being removed by a under-fence pusher mounted on a bobcat.

The pen surface needs maintenance to retain a smooth slope. Areas under shade tend to stay moist and may need more frequent attention.

Once the pens are clean, routine maintenance such as patching potholes can be carried out.

Manure removed from pens is usually transported by truck to a stockpiling or composting area, allowing manure spreading to occur at the most suitable time and independently of the pen cleaning and manure collection process. Efficiency of manure removal is improved by

- minimising idling time during truck loading
- using larger capacity trucks
- loading the trucks in the pen rather than having to transport the manure to the truck. If this is not possible, locate the truck in the stock lane or drain below the pen so that feeding is not disrupted.

Cleaning drains, sedimentation systems and ponds

Drains and sedimentation basins can be cleaned with a box scraper, bowl scraper, grader, front-end loader (in smaller systems) or with an excavator working either from the bank (depending on basin width) or within the system under reasonably dry conditions. Sedimentation tanks can be cleaned using an excavator.

Newly placed gravel under shade being compacted with roller.

Solids that accumulate in the holding pond over time need to be removed eventually.

Front-end loader taking manure to an articulated dump truck during pen cleaning operations.

Excavator being used to clean manure from behind and underneath a fence above a drain.

Options for desludging ponds include

- *Dragline* – produces semi-solid sludge that is difficult to manage. This material should be stored separately from other manure or spread directly.
- *Agitator and pump* – the effluent is agitated to re-suspend the sludge which is then extracted with a chopper or propeller pump for irrigation with a system capable of handling the solids.
- *Excavator* – great care has to be taken to avoid damage to the pond lining.

Some effluent should be left in the bottom of the pond after cleaning to protect the liner and maintain a bacterial population ready to digest the organic matter in the next inflow.

Pen manure

Physical properties of pen manure

The physical properties of pad manure vary with depth: see Table 1.1. Manure consists of moisture and dry matter (DM) or total solids (TS). The organic fraction of the TS, or volatile solids (VS), breaks down over time reducing the total mass of manure solids. The remaining material, fixed solids (FS), is inorganic material that cannot be broken down. The longer manure is stored on the pad, the more VS breakdown occurs.

- about 80% of the TS in excreted manure is VS that is quickly broken down on the pad. Some 60–70% of VS is removed after 20 days, 70% after 35 days and 75% after 80–100 days. (Davis et al. 2010).
- the VS/TS ratio of harvested manure (at pen cleaning) averages 0.64.

This large, rapid loss of VS has significant implications for manure storage and management, greenhouse gas (GHG) emissions and for any advanced treatment technologies described in Appendix 5.

Table 1.1 Typical characteristics of pen manure (Davis et al. 2010)

Manure zone	Moisture content (%)	Fixed solids (%)	Volatile solids (%)
Loose surface layer	22	28	73
Moist loosely-compacted layer	40	33	67
Moist interface layer	22	74	27

The bulk density of pen manure affects the volume of material for removal from the pens. Factors influencing this bulk density include the manure moisture content, manure age, and the amount of soil and rock that is harvested with the manure.

The bulk density of manure on the pad can range from 430 to 1,000 kg/m^3 or even higher for manure containing more soil or rock.

Quantity of pen manure harvested

For many years, the pen cleaning manure removal rate for Australian feedlots was widely quoted to be 1 tonne TS/head/year but some Australian lot feeders have suggested that the real number could be half of this. Calculations of the TS excreted per standard cattle unit (SCU) and decomposition losses suggest that the harvested yield of manure could be as low as 400–420 kg TS/SCU/year.

However, results differ for feedlots that do not retain an interface layer and clean their pens down to the gravel base. These feedlots could be harvesting around 2,000 kg TS/SCU/year made up of manure plus large amounts of gravel, rock or soil.

If bedding is used, this will also be harvested with the manure cleaned from the pens. Wood chips degrade much more slowly than manure so most of the incoming bedding mass will be removed with the manure.

Note: one SCU is equivalent to an animal weighing 600 kg. Scaling factors allow cattle of lower weight to be expressed as SCUs.

Quantity of manure removed

Keeping interface layer

With manure production of 400 kgof TS/SCU/yr and assuming the manure has a bulk density of 650 kg/m^3 and a moisture content of 33%, some 600 kg manure/SCU or 0.9 m^3/SCU of manure would be harvested annually. A full 200 SCU pen cleaned every 13 weeks would yield about 47 m^3 at each pen cleaning.

Scraping to base

With manure production of 2000 kg of TS/SCU/yr and assuming a manure bulk density of 800 kg/m^3 and moisture content of 25% (due to gravel content), some 2700 kg/ SCU or 3.3 m^3/SCU capacity of manure would be harvested annually.

A full 200 SCU pen cleaned every 13 weeks could yield about 170 m^3 at each pen cleaning, but this would greatly depend on how much pen foundation material is harvested.

Composition of pen manure

Pen manure is a rich source of nutrients and organic matter that has potential for utilisation on agricultural land. However, it may also include contaminants that need to be considered in its management. This section provides quantitative data on the composition of pen manure.

The amount of nitrogen (N), phosphorus (P) and potassium (K) in pen manure depends on the composition of the manure excreted by the cattle, but also on climate, pad conditions, pen cleaning practices and the use of dietary or pad additives that reduce volatilisation losses.

The nutrient content of excreted manure is influenced by the class of cattle, their diet, their feed intake and other factors. Gaseous losses of N as ammonia occur rapidly and about 60-70% of the initial N can be lost. This N loss contributes to GHG emissions and also reduces the future fertiliser value of the manure. While some P and K is removed with the manure in runoff and deposited in the holding pond, these minerals are not lost as gas.

A summary of analyses of Australian feedlot pen manure, aged manure and compost manure is shown in *Section 2. Solid waste storage and processing.*

Manure samples can be analysed to determine volatile solid content.

Nitrogen losses are higher under moist conditions.

The weight of manure harvested is greatly affected by its gravel and stone content.

Freshly excreted manure has a high volatile solids and moisture content.

Spoilt feed can be processed with manure.

Ash produced by a coal-fired boiler.

A range of pathogens can be found in feedlot pen manure and very low concentrations of parasiticides and steroids may also be present. Further details are provided in *Appendix 2: Managing human exposure to contaminants.*

Weed seeds may also be introduced through feedstuffs and bedding.

Significant quantities of gravel from the pen foundations and wood chips or other bedding materials may also be included with the manure.

Other wastes

Solid wastes may include spoilt silage and mill run, mortalities and boiler ash.

Spoilt silage and mill run

Well-run feedlots generate only small amounts of spoilt silage and mill run. This waste is usually taken directly to the manure stockpiling or composting area for management.

Mortalities

The average mortality rate in Australian feedlots is generally consistent and low (less than 1%). Management options for feedlot mortalities include

- composting
- burial
- incineration
- rendering.

Most large Australian feedlots compost their mortalities because this yields a usable product. Guidelines for composting mortalities are provided in *Section 2. Solid waste storage and processing.*

Boiler ash

Ash is produced by feedlots with coal-fired boilers for their steam-flaking plants. Ash can be stockpiled for future use in maintaining pen floors and roads.

Further reading

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The amounts of nutrients excreted in manure are influenced by the diet.

BEEF CATTLE FEEDLOTS:
WASTE MANAGEMENT AND UTILISATION

2. Solid waste storage and processing

CONTENTS

The manure stockpiling/composting area needs a durable base to withstand heavy machinery.

Introduction

An area is needed for storing and processing harvested manure, so that pens can be cleaned regularly and manure spreading can fit in with cropping cycles. Few feedlots spread manure directly after pen cleaning although some send manure off-site immediately afterwards. Stockpiling and composting manure reduces its bulk and sometimes the moisture content, concentrates some nutrients and improves handling by breaking up lumps. Space within this area may also be allocated for composting mortalities.

The main facility design considerations for the manure stockpiling/composting area are

- durable, impermeable base
- good site drainage
- sufficient area.

Durable, low permeability base

Manure should be stockpiled and composted on an area with good site drainage and containment.

The base of manure stockpiling/composting areas must be able to handle frequent movement of heavy vehicles. If a risk assessment indicates a high risk of groundwater contamination through nutrient leaching, an impermeable barrier will be needed. Appendix C of the *National Guidelines for Beef Cattle Feedlots in Australia* details geotechnical testing to determine the suitability of soils as 'lining materials' for this area and provides design standards and specifications for clay soils and the constructed liner.

Clay liners should

- achieve a maximum permeability of 1 × 10-9 m/s (0.1 mm/day)
- have a minimum compacted depth of 300 mm to ensure the integrity of the structure is maintained throughout general operations. Compacting gravel over the top may help to protect the lining material.

Good site drainage

The manure stockpiling or composting area needs to sit within a controlled drainage area (CDA). This usually involves the construction of diversion banks although natural topography can be used to divert external 'clean' runoff away from the area. Runoff caught within the area must be directed to a holding pond.

Good drainage within the manure stockpiling or composting area prevents formation of wet patches that can destroy the integrity of the base. An even slope of 1–3% is recommended. Manure windrows need to be orientated with the long axis down the slope to promote drainage.

Poor drainage creates a potential source of odour.

Area needed

The area for manure stockpiling or composting needs to be large enough to store and process the expected amount of manure, to provide an area for mortality composting and to allow for contingency storage. The required area will depend on the amount of manure harvested from the pens, the length of time the manure is stored and the management method.

The way in which manure is managed, particularly at large feedlots, is changing. In 2005, most Australian lot feeders said they preferred to age manure for at least 12 months before it was used, but strong demand for manure at that time often meant that it was being spread or sold after only a few months of aging. About a dozen large feedlots were composting their manure (FSA Consulting 2006).

By 2010, most large feedlots were stockpiling manure for less than 12 months before spreading. The number of large feedlots that were composting had increased to 18 with a cycle averaging six months (3–12 months) and with windrows being turned 7–8 times over this period (O'Keefe et al. 2011). This suggests that most feedlots need space to store at least six months of manure. Feedlots that spread manure annually need 12 months of storage space and additional space for composting mortalities.

Manure windrows should have a triangular cross-section to shed water.

Manure windrows

Manure aging or composting is best undertaken using low windrows rather than large piles. These are more manageable and less likely to catch on fire.

Forming manure windrows

Windrows are typically constructed by forming manure into a long pile with a triangular cross-section, a base width of 3–4 m and a height of 1.5–2 m. A windrow 3 m wide at the base and 2 m high has a cross-section of 3 m^2, and a 75 m long windrow will store approximately 225 m^3 of manure.

The apex and sloping sides promote water-shedding and prevent the manure from becoming too wet, which can result in significant odour. Piles that are too low will not heat up, a process which assists decomposition, pathogen deactivation and weed seed destruction. Piles that are too high may heat up excessively, particularly if they are not well compacted or contain wet manure. Manure fires are a source of odour and smoke and can be difficult to extinguish. Thus wet manure from drains and sedimentation systems should be stored separately and allowed to dry before being added to windrows.

Temperatures and moisture content are checked in windrows to monitor the process.

Windrows should be spaced at least 5 m apart with room at the ends to allow vehicle movement and turning equipment (if used). Their long axes should be perpendicular to the slope to promote drainage.

Manure stockpiling

Manure stockpiling involves forming manure into long, low windrows that are then left to age for some months. The physical properties of manure change over this time making the product more friable and easier to spread than pen manure, while there are also chemical changes. Manure stockpiling can result in environmental impacts, primarily odour from anaerobic breakdown of wet manure while dust and smoke from burning manure can also cause nuisance. These impacts can be largely avoided by restricting windrow height to less than 2 m and promoting good drainage.

Unsuitable moisture content can lead to spontaneous combustion. Stockpile fires are difficult to extinguish.

Quantity of aged manure produced

The harvested yield of manure from feedlots that retain the interface layer is around 0.40–0.42 t of TS/SCU/year (up to 2 t of TS/SCU/year for manure containing large amounts of gravel and/or soil if an interface is not retained).

Space between rows allows for turning.

Truck delivering manure to the stockpile area

After six months, aged manure can be transferred to stockpiles.

Space for windrows

A feedlot that retains the interface layer during pen cleaning will need to provide about 150 m of windrow length per 1,000 SCU capacity. This assumes the manure windrows are 3 m wide at the base and 2 m high, and space is needed to store six months manure production.

If the pens are cleaned back to the pad, up to 750 m of windrow length might be needed, although this will depend greatly on how much soil and gravel is harvested with the manure.

If additional materials are added to the manure for composting, these need to be considered when planning the size of the composting area.

With at least 5 m of space around each windrow for vehicle movements and turning equipment, each windrow with a footprint 75 m long and 3 m wide requires 85 m × 8 m of space plus an additional 5 m of width on the pad overall.

In a feedlot with an interface layer, twenty windrows 75 m long would provide for at least six months storage for every 10,000 SCU on feed. This provides some buffer since the manure decomposes during aging or composting and it may be possible to combine some windrows after three months. Assuming the windrows are stored in a single row parallel to one another, the area needed is 165 m × 85 m (Figure 2.1).

Storage space

Space should be provided for contingency storage of manure that has been through the aging or composting process. Aged or composted manure can be stored in large piles. For a 10,000 SCU feedlot, space for two large piles with a triangular cross section, a base width of 10 m, a height of 4 m and a length of 60 m is suggested. The footprint needed for each of these would be 70 m × 30 m.

Lengthy stockpiling or composting reduces the total dry matter content of the manure by about 35%. For a feedlot with an interface layer, the aged material production would be around 0.26 t TS/SCU/ year which equates to 0.35 t/SCU/yr (total mass) or about 0.6 m3/ SCU/ year at a moisture content of 25% and bulk density of 0.6 t/ m3. The yield from a feedlot that does not retain an interface layer would depend on the rock content and how much material was removed during screening.

Properties of aged (stockpiled) manure

Stockpiling reduces the total mass of manure dry matter, volatile nutrients like nitrogen and often the moisture content, but stable nutrients such as P can become more concentrated. The drop in manure N content with aging or composting is shown in Table 2.1.

Typical analysis results for pen, aged and composted manures from Australian feedlots are presented in Tables 2.5, 2.6 and 2.7. Since the results can vary considerably, lot feeders should analyse their own manure for important agronomic properties just before it is used.

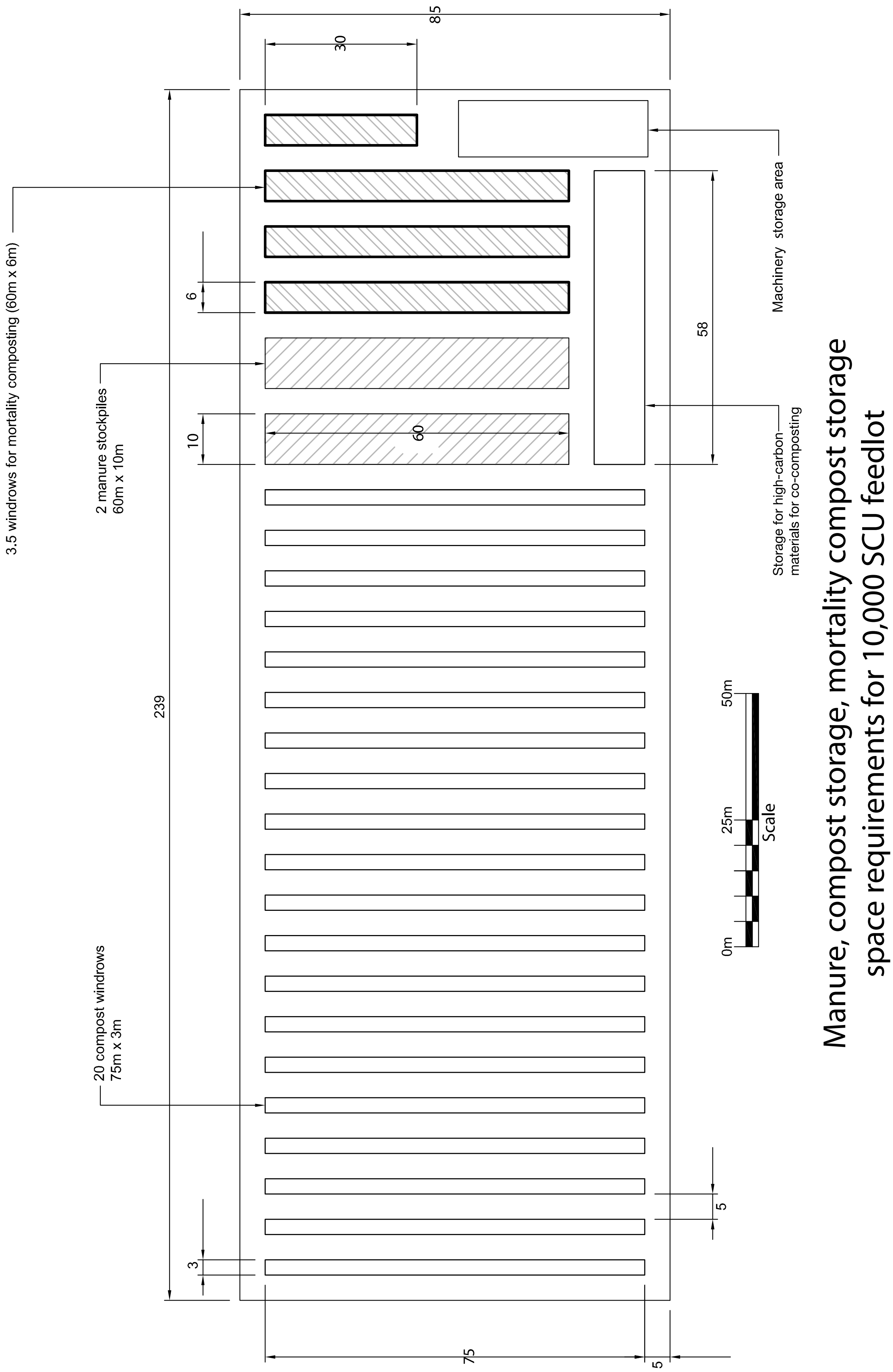

Figure 2.1 Example of space required for composting and storage of manure for a 10,000 SCU feedlot

Table 2.1 Nitrogen content of Australian feedlot manure at different management stages (Davis et al. 2010)

Feedlot	Nitrogen content (%)*		
	Pen manure	Aged manure	Composted manure
Feedlot A	1.7–2.0	0.8–1.0	-
Feedlot D	2.5–3.3	1.9–2.5	-
Feedlot F	1.8–4.5	1.9–2.5	0.7–2.0

Other materials can be blended with manure during the composting process.

Feedstuffs may unintentionally introduce weed seeds into the feedlot diets and ultimately to the manure. Manure may also contain seeds introduced in bedding.

Weed seeds in grain may be sterilised if it is steam flaked. They may be destroyed by the heat generated during aging, although this depends on the temperatures achieved, whether all seeds are exposed to that temperature, the length of time of exposure to that temperature and the weed species.

The risk of weed seeds being present in aged manure can be reduced by using practices that expose all manure to temperatures exceeding 55°C for at least three days, which requires thorough mixing and turning of the windrow, generally at least three times. However, it is difficult to guarantee that the final manure product is free of viable weed seeds.

A range of pathogens can be found in aged feedlot manure. Very low concentrations of parasiticides and steroids may also be present. Full details are provided in *Appendix 2: Managing human exposure to contaminants*.

A probe can be used to measure temperature in the compost windrow.

Manure composting

Composting is the microbiological breakdown of organic matter into compost or humus. Aerobic windrow composting uses organisms that need oxygen to function and is preferred over anaerobic composting because it minimises odour emissions, emits carbon dioxide rather than methane (lower net GHG emissions) and produces heat.

Composting is a more labour and capital intensive process than simply aging manure in static windrows.

Benefits of composting manure

The benefits of composting manure include

- reduced bulk and moisture content of the manure
- more friable and consistent manure which is more easily handled and spread
- possibilities of value adding on or off site
- reduced viable weed seeds and pathogens
- nutrients stabilised into a slow-release form
- reduction in temporary nutrient draw-down that can occur when raw manure is spread on soil
- reduced nitrogen losses on spreading
- increased concentration of phosphorus
- less odour release during aerobic composting

- more predictable nutrients for application to agricultural land or for further processing.

The composting process

Composting consists of an active stage and a curing stage. In the early part of the active stage, readily digestible sugars and starches are rapidly broken down and the temperature within the pile rises to over 40°C (typically 50–60°C). The temperature stays high for several weeks providing there is sufficient nitrogen. Next, the more resistant materials such as lignin are broken down and pathogens are suppressed. Finally, the decomposed organic matter is converted into humus. Once the temperature within the pile drops, the compost can be cured for several weeks. Curing is important since immature compost may have high organic acid levels, a high carbon:nitrogen (C:N) ratio and other properties that can be detrimental to crops.

The steps in windrow composting are

1. Blend the materials for composting. Check that there is sufficient carbon in the manure; it should be in the range of 15–40:1 (ideally 15–25:1). Freshly harvested pen manure may be suitable for composting without amendment or may need additional carbon. Sawdust or wood shavings are ideal for this as they have a C:N ratio of 200–500:1, depending on the timber species. If other materials are to be composted with the manure their carbon and nitrogen content must be determined and the materials thoroughly blended to achieve a suitable C:N ratio.
2. Form the manure into windrows 1.5–2 m high and 3–4 m wide at the base with an apex at the top to shed water. The windrows should be oriented with the long axes perpendicular to the slope to promote drainage. Leave enough space between windrows (at least 5 m) to provide access for turning.
3. Check the moisture content of the material in the newly formed windrow. The composting material has the ideal moisture content if it appears moist but little water can be squeezed from a handful. If it appears dry and no water is released, it is classed as 'dry'; if the compost has water leaking from it without being squeezed, it is classed as 'wet'.
4. If the material is too dry, water the windrow using high pressure jets along the sides. Effluent can be used on this initial watering only; pathogens in effluent make it unsuitable for watering later in the process. If micro-sprinklers are used, the pile must be checked at least every hour during watering to ensure there is no runoff. If the material is too wet, it needs to be turned every couple of days or dry co-composting materials incorporated into the pile until the moisture content is optimal.
5. Monitor the pile temperature and moisture content weekly. The temperature should reach 50–60°C within a week or two. A temperature exceeding 60°C poses the risk of spontaneous combustion. Measure the temperature using a long probe thermometer or thermistors inserted deep into the windrow at ten separate spots along the length of the windrow. Monitor the moisture content by applying the squeeze test to handfuls of compost from an arm-length depth at ten sites along the windrow.

High temperatures during composting will destroy weed seeds.

Compost is turned after at least three days at high temperature.

Effluent being applied by self-propelled windrow turner to raise moisture content

6. If water is available, water material that is ‘dry’, taking care not to over-water.
7. Turn the compost pile only after at least three consecutive days of high temperatures (>55°C). To kill pathogens and weed seeds, the pile should be turned at least three times during the active phase which may take three months or more. Fortnightly turning will minimise labour while creating good quality compost but the pile can be turned more frequently if it has heated sufficiently and equipment and labour are available. A strong temperature rise after turning indicates that active composting is still occurring; if the temperature does not rise markedly, the material is approaching maturity.
8. The active phase is considered complete when manure with a suitable moisture content no longer heats up to >55°C after turning.
9. After completion of the active phase, the compost can be kept in a windrow or formed into a stockpile where it can cure for at least a month.

Tractor-drawn compost turner

Table 2.2 summarises the conditions that promote efficient composting while Table 2.3 provides troubleshooting for common composting problems.

A number of feedlots have differentiated their compost by ensuring their process meets the requirements of *AS 4454: 2012 Composts, soil conditioners and mulches* (Standards Australia Limited 2012). This is necessary to market material as compost and may also attract a premium price, particularly in niche markets.

Composting equipment

Equipment options include
- front-end loaders
- tractor-drawn PTO-driven compost turners
- tractor-drawn self-powered compost turners
- self-propelled straddle turners.

Factors to consider when assessing compost turners include
- *Windrow dimensions* – tractor-drawn PTO-driven, tractor-drawn self-powered and self-propelled compost turners are more suitable for large windrows and can handle larger amounts of compost. Check the amount of space needed between windrows for different types of turners.

Good quality finished compost

Table 2.2 Recommended conditions for efficient composting (FLIAC 2012b)

Parameter	Acceptable range	Optimum range
C:N ratio	15–40:1	25–30:1
Moisture content (%)	45–65	50–60
Oxygen content (%)	>5	>5
pH	5.5–8.0	5.5–8.0
Core temperature (°C)	40–65	55–60
Particle size diameter (mm)	5–50	5–25

Table 2.3 Troubleshooting for common composting problems

Problem	Cause	Solution
Strong odour	Excess moisture	Turn window
	Windrow too large	Make windrow smaller
	Temperature <60°c	Turn window
	Leaf compaction	Turn/reduce windrow size; eliminate ponding
	Surface ponding	Apply odour masking agent (addresses symptom only)
Low windrow temperature	Windrow too small	Combine windrows
	Insufficient moisture	Add water while turning
	Poor aeration	Turn windrow
High windrow temperature	Windrow too large	Reduce windrow size
	Leaf compaction	Turn windrow
Surface ponding	Depression or ruts	Fill depression and/or regrade
	Inadequate slope	Grade site to recommended slope design
Vectors (rats, mosquitoes)	Presence of garbage (food etc)	Remove garbage or use rat bait
	Presence of stagnant water	Eliminate ponding
Fires/spontaneous combustion	Excessive temperature	Make windrow smaller
	Inadequate moisture	Add water
	Stray sparks, cigarettes etc	Keep potential fire sources away from windrows
		If fire does start, break windrows apart and extinguish completely

(Biocycle & Composting Equipment Pty Ltd ND)

- *Turning rates* – three-point linkage models can generally turn 200–400 m^3/hr, tractor-pulled units 400–800 m^3/hour and self-propelled turners 1,200–6,500 m^3/hour.
- *Power requirements* – tractor power required depends on turner size. Tractors of 35–45 kW will generally be needed for three-point linkage turners, while a PTO-driven unit might need 60–100 kW. The tractor will need a creeper gear for slow-speed travel or hydraulic assist on the turner.
- *Turning method* – straddle turners turn the windrow in a single pass so the windrow width must match the drum length. Auger turners that lift and move the compost to one side using paddles are well suited to composting in small areas as less tractor space is needed beside the windrow.
- *Watering* – turners that can add water using a trailing hose system are suited to medium to large operations and improve operating efficiency. Turners that can tow a water tanker that applies water during turning may suit small operations.
- *Amount of manure* – front-end loaders are suitable at small operations because they may already be available on-farm and have a range of uses. However, they are generally too slow for larger quantities of manure and may not thoroughly mix the pile. Three-point linkage units suit small to medium scale composting. Purpose-built compost turners that mix the compost using an auger, rotary drum with flails or an elevating conveyer are best for large-scale operations.


Windrow turned with a front-end loader

Composted manure has a fine, even structure.

Finished manure or compost can be stored in large stockpiles.

Quantities of manure compost produced

The rate of compost production depends on whether other materials are added (co-composting). Composting generally reduces the initial volume of material by 60–70%.

To optimise the composting process, the initial moisture content of the manure should be 40–65%. Assuming no additional materials are added, there is about 0.8 t/SCU/year of manure for composting (at a moisture content of 50%). At a bulk density of 0.6 t/m^3, this gives some 1.3 m^3/SCU/year of material initially.

If 35% of the TS is lost in the process and the moisture content drops to 25%, the final yield of compost is 0.35 t/SCU/year (or 0.46 m^3/SCU/year at a bulk density of 0.75 t/m^3).

Properties of manure compost

Typical analyses of manures and compost (Tables 2.5, 2.6 and 2.7) are presented on pages 16 and 17. Since results can vary considerably, particularly if co-composting is practiced, lot feeders should analyse their own compost to ascertain its properties.

While composting may well destroy weed seeds by heating, the effective loss of viability depends on a range of factors. While most weed seeds are likely to be destroyed, feedlot compost cannot be guaranteed weed-free.

Similarly, after two to three months of composting, most pathogens should have been substantially reduced in numbers but some pathogens may still be present in the finished compost. Very low concentrations of parasiticides and steroidal hormones may also be present. Full details are provided in *Appendix 2. Managing human exposure to contaminants*.

Composting will not remove harmful inorganic metals or strong acids or alkalis (which are likely to impede the process) and may produce small amounts of some plant and animal toxins, although this is more likely in poorly managed systems

Composting feedlot cattle mortalities

Mortalities have to be removed quickly from the pen, and most large Australian feedlots use windrow composting for managing them.

Windrow systems are

- readily adaptable to any number and size of carcases
- easily formed with typical farm equipment
- low maintenance.

Mortalities can also be composted in bins or piles. Bin composting involves the use of separate bays for each stage of composting (primary, secondary and curing) but this method is often impractical because the large bodies of cattle are difficult to place in the bins. Composting piles consist of layers of carbon source and carcases formed into a cone or hemisphere shape. Piles are not recommended because the large surface area promotes heat loss and rapid drying and it is difficult to turn the pile.

For and against composting mortalities

Advantages and disadvantages of composting are summarised by Animal Health Australia (2010):

Advantages

- can be done on-site
- commercial operators exist
- most feedlot operators are familiar with the composting process
- produces a useful, biologically stable, saleable product that is safe for the environment
- reduces odour and attracts few insects
- leachate is absorbed
- quick response possible for a medium-scale incident
- kills most disease agents if properly implemented and managed.

Disadvantages (especially if applying to mass disposal)

- can be difficult to implement in the event of emergency animal disease involving large numbers of mortalities
- needs a large land area
- needs heavy machinery to construct and manage the pile
- needs suitable mortality transport
- requires large amounts of high carbon material
- needs regular turning after the first 3–4 months
- need to control runoff and run on
- need to consider soil type and water table
- may need to manage pests (birds, insects, foxes, feral pigs)
- potential odour risk if not well managed
- needs good control and monitoring
- possible biosecurity risk if high temperatures are not reached
- process takes time and may affect release from quarantine
- unsuitable for destroying spore-forming organisms or animals affected by transmissible spongiform encephalopathies.

Mortalities can be composted in piles.

Some feedlots compost mortalities in bays.

Design principles for mortalities composting areas

The design principles for a mortalities composting area match those for a manure stockpiling or composting area. Thus, mortalities are often composted in this area.

The main facility design considerations are

- durable, low permeability base
- good site drainage
- sufficient area.

The area needed depends on the method of composting: bin, pile or windrow.

Windrows with a trapezoidal cross section are most commonly used for mortality composting. At least 2.5 m of windrow length is needed for each tonne of carcases. The mass of mortalities depends on the size of the feedlot, the mortality rate and the average weight of individual mortalities. Sufficient space should be provided between windrows to allow for construction and maintenance.

Areas for composting mortalities need a well-compacted base.

Runoff and leachate from the mortality composting area must be controlled.

Mortalities composting process

In conventional composting processes, raw materials are typically mixed to provide an optimal C:N ratio, a moisture content of 50–60% and good porosity. The materials are then regularly turned. However, the mixture is inconsistent with mortality composting. Cattle bodies have a large mass, a high moisture content, a low C:N ratio and almost no porosity. Consequently in the initial stage, the decomposition process close to the carcass is anaerobic. The fluids and gases released then move into an aerobic zone.

The recommended process for windrow composting of mortalities involves

- Using a front-end loader bucket, spread a 0.3-0.6 m-deep base of absorptive material such as sawdust or waste straw that will contain fluids released during decomposition. The base should be about 5–5.5 m wide as this will allow two carcases to be lain side-by-side. Increase the width to 7 m if mortalities will be stacked two high.
- Promptly transporting mortalities to the composting area to reduce the risk of disease transfer. Mortalities that may be infected should be lifted and carried from the pens if possible. Dragging looks bad and may release body fluids that could pose a biosecurity risk to workers and other stock. Do not use equipment used for feed processing (e.g. front-end loaders) to transport mortalities or to handle compost.
- Place carcases in a single layer on top of the absorptive layer. If the windrow will be two carcases wide, place the spines of the animals in the centre of the pile and legs on the outer edges as this exposes the bulk of the body to the highest temperatures. Generally, the thoracic cavity is opened and the rumen punctured, but not if the likely cause of death is an infectious disease.
- Cover the bodies completely with at least 0.5 m of manure or sawdust. A second layer of carcasses can be added on top and surrounded with a further mimimum of 0.5 m of cover material. It is important to maintain good cover continuously to promote composting and prevent access by insects and birds that could transmit disease vectors. Allow at least 2.5 m of windrow length for each tonne of carcasses.

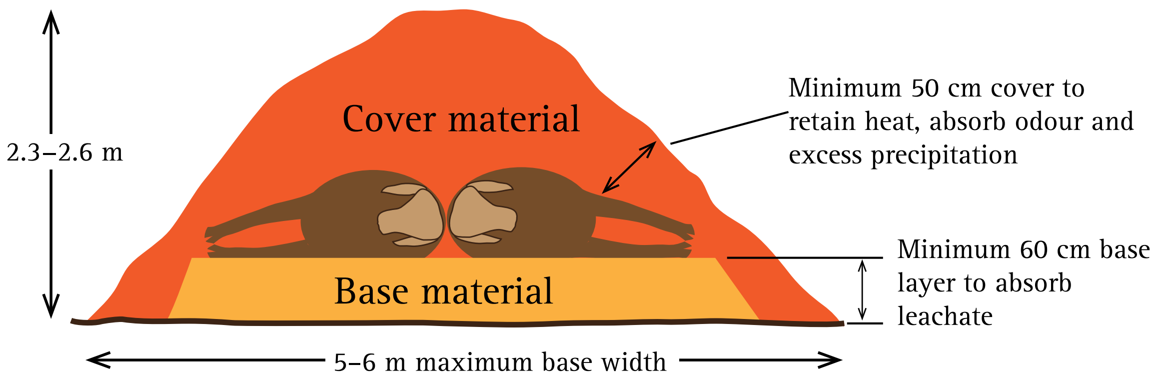

Figure 2.2 Placement of carcasses side-by-side for composting

- Ideally, the cover material will have an initial moisture content of 50– 60% and will feel moist. If the cover material is too dry, adding moisture by applying effluent through micro-sprinklers running along the top of the windrow. High pressure jets may also introduce micro-organisms that are beneficial to the process. Otherwise water can be used.
- Monitor core temperatures weekly during the active stage using a long-stemmed thermometer or thermistors at 10 spots along the windrow. Temperatures should reach 50–60°C within 2–3 days and remain high for at least two weeks.
- The carcase windrow should be turned and watered (if required) but only after the organic material has broken down into mall particles and the bones partially softened (typically 4–6 months).
- The active stage is completed when the pile no longer heats above about 30°C after turning, and the material is low in odour, a dark brown to black colour and humus-like. This typically takes at least 6-8 months. Turning is recommended at this point.
- Curing can then occur. The material can be formed into a pile for this purpose. Microbial activity during curing will remove plant inhibitors from the compost. Allow 12 months in total for active composting plus curing. To prevent regrowth of pathogens, composted material should be kept separate from uncured material.
- The finished material can be screened to remove any remaining bones.

Placing waste straw under the carcass helps to aerate the pile.

Composting carcasses must be kept covered.

Jawbones and teeth often remain after composting is completed.

Yield of carcase compost

Assuming carcases are composted in a 1:1 ratio by weight with manure and the combined moisture content of the manure and carcases is 60%, there will initially be 0.4 t TS/t. If 50% of the TS is lost by decomposition throughout the process, there will be about 0.2 t TS on completion. At a moisture content of 25% and a bulk density of 0.7 m^3/t, there will be about 0.54 t or 0.76 m^3 of compost for every tonne of carcases.

Properties of carcase compost

Since animal bodies have a high nutrient content, carcase compost has a greater nutrient density than manure compost. It could be expected to contain around 1.6% N, 0.6% P and 1.1% K on a wet basis; and 2.1% N, 0.8% P and 1.5% K on a dry basis. However, the composition of compost at a given feedlot will depend on the type and amount of covering material. Chemical analysis of finished compost is recommended.

The pathogen content of cured carcase compost has been found to pose a risk similar to that of manure compost. Thus, this method of mortalities management is acceptable provided high temperatures are achieved.

The rumen is commonly punctured before composting, but not if death was possibly caused by an infectious disease.

Windrows are the most suitable for composting large numbers of mortalities.

Mortality compost can be put in a stockpile to cure.

How much windrow space for composting mortalities?

Carcases of lighter (short-fed) cattle need less space for composting. Assuming an average weight of 350 kg, every 10 mortalities would weigh 3.5 t and so would need about 9 m of windrow length to be provided for composting.

Carcases of heavier (long-fed) cattle need more space for composting. Assuming an average weight of 450 kg, 10 mortalities would weigh 4.5 t and would need about 11.5 m of windrow length to be provided for composting.

The total space needed will depend on the number of mortalities each year, their weight and the length of time the compost is kept in windrows.

Emergency composting of large numbers of mortalities

Composting is a suitable method for disposal of cattle mortalities of all sizes. However, it may be difficult to implement as an emergency disposal response where there are large numbers because of the amount of carbonaceous material needed, the time taken to complete the process and difficulties in ensuring a uniform process. Even if approval has been obtained for mass disposal by composting on-site, the relevant environment protection agency should be involved and provide a representative for the disposal team.

In general, follow the process previously described. If an infectious disease is the cause of death, additional precautions should be taken when composting. The following will help to reduce the risks of pathogen survival and disease transmission

- Do not puncture the rumen or open the body.
- To achieve high temperatures that are able to kill pathogens as quickly as possible, cover the carcases with silage or a 0.15–0.30 m layer of moist manure that is then covered with ground straw for a total depth of at least 0.6 m. For every 450 kg animal, about 9 m^3 of high carbon material will be needed.
- Do not turn the pile during carcase decomposition as this can increase the risk of pathogen release into the wind.
- Do not excavate and spread compost until approved by the Chief Veterinary Officer. In emergencies involving highly contagious diseases, the Chief Veterinary Officer may require burial or incineration of the finished compost.

Where the livestock deaths are not the result of disease, the following apply

- Dry, porous materials that do not necessarily produce high temperatures as quickly can be used as cover material – feedlot manure is often suitable.
- The compost pile can be turned after 60–90 days, although this is not necessarily needed.
- Excavation and spreading of compost can occur once the soft tissues and internal organs are fully decayed (usually 8–12 months after commencement of the process).

Emergency composting of mass mortalities

In response to the outbreak of foot and mouth disease in Great Britain in 2001, the Iowa Department of Natural Resources funded a three-year project into emergency disposal of livestock mortalities. The project produced draft guidelines for emergency composting of cattle mortalities (Iowa State University 2002). The following recommendations are based on those guidelines.

The composting site should

- avoid unnecessary transport of mortalities that might spread disease
- be accessible by large trucks if cover materials will need to come from off-farm
- be well separated from receptors and public use areas
- be situated on well-drained land that is not subject to runoff or ponding and is outside the 1-in-100 year flood line
- be well separated from bores, streams and areas of exposed bedrock
- be close to agricultural land where compost can be utilised on crops that are not consumed directly by humans or grazing livestock.

Composting is appealing for emergency disposal of mortalities as it provides for rapid, on-farm containment of mortalities. The high temperatures generated during composting help to destroy pathogens. Most feedlots have the equipment and materials needed to undertake composting.

The finished material can be screened to remove any remaining bones.

Compost and manure screening

Screening is used to remove rocks and other debris from manure and bone fragments from carcase compost. These are removed to avoid damage to spreading equipment and the distribution of physical contaminants onto utilisation areas. Screening also converts lumpy manure into a loose, friable product that can be spread more evenly. However, screening is costly.

Compost passing through a gravel screen

Maintaining an interface layer when pen cleaning minimises the amount of rock in the manure and consequently the screening costs.

Most large Australian feedlots screen manure and carcase compost as part of their standard practice, usually just before spreading or on-selling. Some feedlots screen manure before composting to avoid damage to the turning equipment.

Trommel screens, or rotating cylinder screens, can be constructed as portable stand-alone units or smaller units that can be attached to excavators and front-end loaders.

Screening converts lumpy compost into a loose, friable product that can be spread more evenly.

Managing waste feed

In well-run feedlots, feed wastage through spillage or spoilage is generally low. If a significant quantity of feed is spilled along the front of the feed bunks, it should be collected and taken to the manure storage or composting area — a bobcat is useful for this task. If some feed becomes wet and unpalatable in rainy weather or if cattle go off their feed under wet or hot conditions, it needs to be

Spilt feed should be collected and taken to the manure storage or composting area.

Rotating brush cleaners can be used for feedbunk cleaning.

Screening is used to remove rocks and other debris from manure and bone fragments from carcass compost.

removed from the bunk, often manually using brooms and shovels, before the next feed delivery. The spoilt feed is generally thrown onto the pen surface where it mixes with the manure and is removed at pen cleaning. Rotating brush cleaners are available for feedbunk cleaning, and should throw the waste feed into the yard rather than onto the road.

Grain screenings and spoilt silage can be removed from the milling or feed preparation area to the manure storage or composting area for management with the manure.

Using boiler ash

Coal-fired boilers produce ash that must be managed. Coal ash is mainly carbon with oxides of aluminium and iron but has virtually nil nutrient value.

Table 2.4 Composition of ash from a coal-fired boiler

Parameter	Content
Carbon (% db)	31.7
Silicon in plant tissue (% db)	7.4
Sulfate (mg/kg db)	1,800
Aluminium (mg/kg db)	1,900
Iron (mg/kg db)	5,700

Coal ash mixed with soil may be useful for filling potholes and patching high use areas (e.g. behind aprons) of the feedlot pad or roads. Fly ash mixed with soil yields a product with good engineering properties for feedlot surfacing.

Table 2.5 Typical composition of Australian feedlot pen manure (dry matter)

Parameter	Average level	Minimum level	Maximum level	No. of samples
Dry matter (%)	66.0	19.6	95.6	161
Total nitrogen (% db)	2.5	0.95	4.1	85
Total phosphorus (% db)	0.96	0.75	1.21	21
Potassium (% db)	1.86	0.73	2.92	21
Sodium (% db)	0.33	0.08	0.50	27
Sulfur (% db)	0.44	0.31	0.56	26
EC1:5 (dS/m)	14.7	9.1	18.8	21
Ammonia-N (mg/kg db)	1,797	130	6,430	53
Nitrate-N (mg/kg db)	120	1	390	38
Copper (mg/kg db)	43.8	11.0	68.0	23
Iron (mg/kg db)	11,783	1900	27,000	23
Zinc (mg/kg db)	280	79	430	23

Table 2.6 Typical composition of Australian feedlot aged (stockpiled) manure

Parameter	Average level	Minimum level	Maximum level	No of samples
Dry matter (%)	63.2	37.2	89.0	22
Total nitrogen (% db)	2.18	1.10	3.30	71
Total phosphorus (% db)	0.80	0.52	1.10	63
Potassium (% db)	1.86	0.75	3.2	71
Sodium (% db)	0.30	0.04	0.70	65
Sulfur (% db)	0.45	0.18	0.77	62
Calcium (% db)	2.22	0.77	3.80	66
Magnesium (%db)	0.86	0.24	1.58	65
EC1:5 (dS/m)	8.26	0.16	17.2	59
pH	7.22	6.3	8.66	62
Ammonia-N (mg/kg db)	1,431	0	3,800	45
Nitrate-N (mg/kg db)	307	1	1,115	26
Boron (mg/kg db)	21.5	1.9	54	37
Cobalt (mg/kg db)	7.0	2.3	15.0	13
Copper (mg/kg db)	34.5	3.9	59.0	41
Iron (mg/kg db)	11,717	200	27,000	34
Manganese (mg/kg db)	387	53	870	41
Molybdenum (mg/kg db)	4.28	0.80	12.00	25
Ortho-phosphate (mg/kg db)	944	4	2,909	15
Zinc (mg/kg db)	221	70	420	64

Table 2.7 Typical composition of Australian feedlot composted (windrowed) manure

Parameter	Average level	Minimum level	Maximum level	No. of samples
Dry matter (%)	74.0	53.6	94.4	27
Total nitrogen (% db)	2.11	1.30	2.80	30
Total phosphorus (% db)	1.31	0.49	2.61	22
Potassium (% db)	2.49	0.96	3.40	20
Sodium (% db)	0.43	0.07	0.99	21
Sulfur (% db)	0.52	0.02	0.89	18
Calcium (% db)	2.47	0.50	5.56	22
Magnesium (%db)	0.93	0.24	1.77	21
EC1:5 (dS/m)	16.1	2.8	24.8	8
pH	7.3	7.0	7.8	9
Ammonia-N (mg/kg db)	1,016	17	2,200	16
Nitrate-N (mg/kg db)	588	0	1,700	14
Boron (mg/kg db)	22.8	2.8	42.0	14
Copper (mg/kg db)	36.9	3.0	70.0	20
Iron (mg/kg db)	5,266	100	12,000	18
Manganese (mg/kg db)	351	30	630	19
Molybdenum (mg/kg db)	5.67	2.40	13.00	5
Ortho-phosphate (mg/kg db)	3,115	11	7,521	8
Zinc (mg/kg db)	254	89	410	19

Further reading

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BEEF CATTLE FEEDLOTS:
WASTE MANAGEMENT AND UTILISATION

3. Management of odour, dust and flies

CONTENTS

Manure is most odorous two days after wetting.

Even small areas of wet manure can be significant sources of odour.

Sedimentation basins are generally more odorous than holding ponds.

Introduction

Odour, dust and flies can cause conflict with neighbours, create an unpleasant workplace and affect cattle performance and staff welfare.

Sources of odour

Odour at cattle feedlots is mainly the result of anaerobic breakdown of organic matter, primarily in manure but also in waste feed. While good siting and feedlot design (particularly drainage) are vital in minimising odour, good hygiene and waste management are also imperative.

Odour release sites at a feedlot can include

- pens and cattle handling facilities
- drainage systems including sedimentation tank or basin and effluent holding pond
- feed storage and preparation areas and silage pits
- manure and effluent utilisation areas.

Two days after wetting, odour emissions from wet feedlot manure can be 50–100 times higher than those from dry pads and the odour is more offensive. Even a relatively small area of wet manure could be a significant odour source.

Pad temperature and moisture content are the most important factors influencing odour emissions from the pen (Nicholas et al. 2004). However, the depth of manure influences the rate of pad drying and hence the length of time over which higher odour levels persist.

Odour emission rates for sedimentation basins are generally greater than those from holding ponds. Pond rates under stable conditions are generally very low, but they can suddenly increase greatly after a significant inflow.

Odour from manure stockpiles, compost piles and silage pits are similar to those of feedlot pads. The character of odour from these sources seems to be less offensive than those from pads and ponds.

To minimise odours, limit the depth of manure over the pad, maintain an even feedlot surface and use practices that facilitate rapid drying of manure. Odour is reduced by cleaning pens frequently, and regularly removing

- manure or waste feed that has accumulated under fencelines and may impede drainage
- manure that accumulates along feedbunks, water troughs and aprons
- manure that settles in the drains, settling pit or sedimentation basin after rainfall.

As manure stockpiling areas can be a source of odour under wet conditions, good drainage from the windrows themselves and the pad is important. Section 2 provides more details.

Odour control

Areas or activities where there are opportunities to control odours include

- pen cleaning
- cleaning of drains and sedimentation tanks and basins
- pond desludging
- manure screening
- manure spreading
- effluent irrigation
- disposal of mortalities.

As there is some flexibility in the timing of these activities, it is useful to have a basic understanding of atmospheric conditions that can disperse odours.

Atmospheric conditions and their effects on odour dispersal are:

- Unstable atmosphere – typically the atmosphere is unstable on a warm sunny day when hot eddies of air rise from the land surface and cause significant mixing of the atmosphere. Odours are rapidly dispersed and carried upwards, quickly reducing odour intensity away from the feedlot. Because these conditions promote rapid dispersion, they are ideal for carrying out most odour-generating activities.
- Stable atmosphere – occurs on cold, still clear nights when the air at the land surface stays cool and remains trapped below an inversion layer. Little atmospheric mixing occurs below this layer and there is little dispersal of odours. Odours remain at relatively high intensity at some distance from the feedlot. These conditions are unsuitable for undertaking activities that will generate significant odour.
- Neutral atmosphere – occurs on heavy overcast days and odour dispersion is only moderate.

Effluent and manure utilisation should occur only when the prevailing weather conditions are unlikely to result in odour and dust nuisance for nearby residents. Consider the wind direction and strength, the time of day and the atmospheric stability. A plan showing the location of all nearby neighbours and a simple wind vane will help to show which neighbours are at risk of odour nuisance from effluent or manure utilisation on particular fields. It is also useful to understand the relative sensitivities of different neighbours to odour.

It can be worthwhile to develop an annual utilisation plan that takes into account seasonal wind directions, rainfall patterns and crops grown. Different paddocks might be selected for utilisation at different times of the year depending on risk.

To reduce odour nuisance to neighbours, spread manure or irrigate effluent

- frequently to minimise events with large odour generation
- evenly
- in the morning when the air is warming rather than late in the afternoon

Good pen foundations help to reduce problems of odour or dust.

On cold, still mornings, air will be trapped below an inversion layer, restricting odour dispersion.

Do not spread manure if heavy rain is predicted.

Suitable bunk design prevents build up of manure and associated problems of odour and flies.

Cattle movements along lanes can be a significant source of dust in dry conditions.

A water cart can be used to suppress road dust.

- as close to the ground as possible, particularly for spray irrigated effluent
- then as soon as possible harrow, disc or chisel plough to incorporate manure into the soil
- spray effluent as close to the ground as possible, and avoid high-pressure guns.

But do not spread (or irrigate)

- if the wind is blowing towards a neighbour
- if rain or heavy cloud are expected – use weather forecasts
- just before weekends or public holidays, particularly if close to a public area
- very dry manure that will result in dust being blown towards neighbours.

Also

- Eliminate all wet patches in drains and yards
- Avoid stockpiling wet manure as this produces very strong odours, even after spreading
- Train all staff in the mechanics and importance of odour dispersion
- Undertake public relations exercises – advise neighbours before spreading manure or irrigating effluent, even if winds will not blow towards them.

Dust control

Dust in feedlot pens should be controlled for the comfort and safety of cattle and workers, and to avoid impacting amenity. The health effects of dust depend on their concentration, size distribution, composition and persistence. Large dust particles (>10 µm) are typically responsible for adverse aesthetic impacts (e.g. soiling and discolouration) rather than health concerns. Finer dust particles are strongly linked to respiratory symptoms; these fine particles can remain suspended in the atmosphere for days and travel long distances.

Dust concentrations can be high downwind of feedlots, with a peak concentration typically seen around sunset with increased cattle movement and stable atmospheric conditions at that time. However, nuisance dust from the feedlot is unlikely to travel far enough to cause nuisance above that from other agricultural activities.

Control dust by minimising the depth of manure over the pad, by managing the moisture content of pad manure and by watering roads and lanes. For most feedlots, dust will need to be controlled only periodically.

Temporarily increasing the stocking density is one way to add moisture to the feedlot pad as it increases the rate of urine and faeces added to a given area. However, the capacity to vary stocking density may be limited by the conditions of the feedlot's licence or permit.

Mobile water tankers are useful for controlling dust on roads and lanes. Controlling dust loss reduces the exposure of sharp gravel so watering roads may provide an additional benefit through reduced wear and tear on tyres. Typically tanker sizes range from 20,000–25,000 L up to 40,000 L capacity. These tankers should be fitted with 30–90 kW pumps to supply a discharge rate of 2,000–10,000

L/min. Depending on the design of the tanker nozzles, water can be spread in a band 2–24 m wide (Sweeten and Lott 1994). The main determinant of tanker efficiency is turnaround time for loading and travel between the load and spreading points. In large feedlots, this can be minimised by providing multiple fill-up points. Roads can also be sealed to eliminate dust from this source.

Amending feedlot pad surfaces with wood chips might cushion hoof impact that causes dust and reduce dust directly by decreasing evaporation from the pad.

Since pen cleaning disturbs pad manure and creates dust, it should be avoided when the manure is very dry. However, the pens still need to be cleaned at an acceptable frequency (see Section 2).

Spreading dry manure can generate significant dust and should be avoided, especially under windy conditions.

Sealing internal roads is costly but greatly reduces dust.

Fly control

Feedlot operators consider flies to be a nuisance. The most important impacts (Vrech et al. 2004) are

- poorer working conditions
- risk to human health
- spoilage of feed
- poorer animal welfare
- potential for chemical residues
- production losses.

Dust released during manure spreading

Of the major fly species found at feedlots, only house flies and stable flies breed at the feedlot; other species predominantly breed elsewhere. Flies breed in a number of relatively small areas, the most common being manure, vegetation and moist areas e.g. in hospital and induction areas, under fence-line manure, drains, silage pits and heavily grassed areas adjacent to the feedlot.

Pen cleaning has a short-lived effect on fly breeding since manure quickly builds up under fences after cleaning. Because this manure is not trampled by the cattle it provides a good larvae habitat. Most feedlots use fly control including baits, insecticide sprays and traps. Fly baits have limited effectiveness as they attract and kill only adult house flies. There are also resistance issues with these. On the whole, insecticidal treatments have limited effectiveness.

Integrated pest management (IPM) systems that incorporate mechanical, physical, biological and chemical controls are likely to be most effective.

The RULES developed for IPM for control of nuisance flies at a feedlot site (based on Urech et al. 2004) are:

- Reduce fly breeding sites through
  - good manure management: clean under fencelines, sedimentation basins, drains, hospital pens and manure stockpiles
  - clean up feed spilled near the bunks, hospital pens, stables and feed mill

Fly bait station

Regularly mowing grassy areas around feedlot pens reduces habitats of fly larvae.

Vegetation growing into sedimentation basins and holding ponds provides a site for flies to breed.

  - good feedstuff storage – some ingredients, such as molasses and silage, attract more flies. Clean up spills and keep silage well covered
  - appropriate mortalities management – compost and cover completely
  - maintaining the feedlot troughs, drains, sedimentation basins and vegetation management by mowing or slashing around the feedlot complex, particularly areas adjacent to drains and pens

- Using insecticides selectively
  - rotate chemical groups
  - target insecticide use towards hot spots
  - use residual adulticides, particularly on resting sites rather than manure
  - use larvicides that will not affect beneficial insects
  - use baits for house flies with rotation between chemical groups.

- Lot feeding design principles, including
  - suitable pen foundation and slope
  - good feed bunk and water trough design
  - fence design that allows for easy cleaning
  - good construction of drains, sedimentation systems and effluent holding ponds
  - well-designed manure stockpile and composting area.

- Enhancing populations of biological control agents through
  - biological control agents, such as parasitic wasps, predatory mites and entomopathenogenic fungi, that can play an important role in killing larvae and flies; further development is needed
  - sustaining target parasite and predator populations through appropriate management
  - boosting parasite populations through strategic releases.

- Systematically monitor fly populations by
  - scouting adults and larvae to determine population thresholds
  - using traps for adults; larval density ratings for immatures
  - observing animals.

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BEEF CATTLE FEEDLOTS:
WASTE MANAGEMENT AND UTILISATION

4. Liquid wastes

CONTENTS

Drains direct runoff into a sedimentation system or holding pond.

A weir filters effluent runoff and allows solids to settle in a sedimentation basin.

Cattle washing and vehicle washing can contribute to the effluent load.

Introduction

The main liquid waste from cattle feedlots is the effluent resulting from storm water runoff from the pens. This waste must be properly contained and managed as it is rich in nutrients and also has a significant microbial load.

Runoff control facilities

All feedlots must sit within a controlled drainage area (CDA). The design of the CDA must incorporate

- Drains or similar structures that capture contaminated runoff from within the feedlot complex and divert it to a sedimentation system and then holding ponds.
- A sedimentation system that removes entrained settlable solids and organic nutrients from the effluent. When significant solid material accumulates, the sedimentation system should be cleaned out. In wetter climates, having two sedimentation systems in parallel will allow one to be dried and cleaned while the other is in operation.
- A holding pond or ponds large enough to store runoff from the CDA without spilling or overtopping at an unacceptable frequency (e.g. an acceptable average spill recurrence interval might be 10, 20 or 50 years depending on the site). These ponds store stormwater runoff until it can be spread on land or evaporates.
- Appropriately-designed weirs, by-washes and channels to capture excess runoff during overtopping or spill events in the sedimentation system and holding pond.
- Diversion banks or drains placed immediately upslope of the feedlot complex to divert 'clean' storm water around the complex.

Details of the cleaning and maintenance of these facilities are provided in Section 1.

Quantity of effluent produced

The major source of effluent is runoff from the CDA of the feedlot, with volume depending on the size of the CDA, the intensity and amount of rainfall and manure management.

The MEDLI model (see Glossary) has been used by Tucker et al. (2010)to simulate the effluent yield for model feedlots located in the five main lotfeeding regions of Australia

- central Queensland (Comet)
- southern Queensland/northern New South Wales (Dalby)
- central New South Wales (Quirindi)
- Riverina (south-western NSW/north-western Victoria) (Charlton)
- south-west Western Australia (Mt Barker).

For each location Table 4.1, Table 4.2 and Table 4.3 show the feedlot pond water balance, including runoff yield, of 5,000 SCU, 10,000 SCU and 25,000 SCU feedlots.

Additional effluent is generated in feedlots that wash cattle. Water use for cattle washing typically ranges from 800 L/head to 2,600 L/head depending on the dirtiness of the cattle and the requirements of the abattoir.

A small amount of wastewater is created by cleaning water troughs to remove feed and algae that can foul the water and reduce cattle intake. The amount of water used for trough cleaning depends on cleaning frequency, trough size and clean water inflow during cleaning but is typically 0.1–3 L/head each month.

Cleaning induction and hospital areas can use around 1.3 L of water/head/month while vehicle washing facilities can use around 1.2 L/head/month.

Table 4.1 Feedlot pond water balance for a 5,000 SCU feedlot

Long-term annual average		Comet	Dalby	Moree	Quirindi	Charlton	Mt Barker
In-flows	Rainfall on pond (ML*)	13.2	8.3	6.9	9.5	2.9	6.6
	Inflow of runoff (ML)	33.0	34.4	31.5	30.7	15.9	23.8
Out-flows	Evaporation (ML)	24.0	16.3	12.9	13.8	4.3	6.1
	Seepage (ML)	0.6	0.4	0.4	0.5	0.3	0.2
	Overtopping (ML)	0.2	0.2	0.3	0.2	0.2	0.1
	Extracted (ML)	21.4	25.5	24.8	25.6	14.0	24.0
	(% of inflow)	46%	60%	65%	64%	75%	79%

*ML (megalitre) = 1,000,000 litres

Table 4.2 Feedlot pond water balance for a 10,000 SCU feedlot

Long-term annual average		Comet	Dalby	Moree	Quirindi	Charlton	Mt Barker
In-flows	Rainfall on pond (ML)	27.7	21.4	15.4	18.0	8.9	16.2
	Inflow of runoff (ML)	65.2	69.2	63.4	61.8	32.1	47.5
Out-flows	Evaporation (ML)	52.6	44.9	31.3	28.2	15.4	17.1
	Seepage (ML)	1.3	1.1	0.8	0.8	0.5	0.7
	Overtopping (ML)	0.2	0.2	0.2	0.2	0.1	0.1
	Extracted (ML)	38.7	44.4	46.6	50.5	25.0	46.0
	(% of inflow)	42%	49%	59%	63%	61%	72%

Table 4.3 Feedlot pond water balance for a 25,000 SCU feedlot

Long-term annual average		Comet	Dalby	Moree	Quirindi	Charlton	Mt Barker
In-flows	Rainfall on pond (ML)	61.2	38.5	31.2	42.9	11.2	44.1
	Inflow of runoff (ML)	163.6	172.6	157.9	153.7	80.0	119.7
Out-flows	Evaporation (ML)	122.4	83.1	66.9	72.2	20.8	50.7
	Seepage (ML)	3.1	1.9	1.7	2.1	0.7	2
	Overtopping (ML)	0.3	0.5	0.8	0.5	0.7	0.3
	Extracted (ML)	99.0	125.6	119.7	121.8	69.0	110.8
	(% of inflow)	44%	59%	63%	62%	76%	68%

A holding pond retains effluent until it evaporates or can be used for irrigation.

Sampling effluent ponds for analyses

Feedlot storm water runoff carries a significant bacterial load but this reduces rapidly.

Effluent composition

Chemical composition of effluent

The wide range of levels of nutrients and solids that can be expected in effluent from Australian feedlot holding ponds (Table 4.4) illustrates why effluent management must be based on site-specific effluent analyses.

Table 4.4. Effluent quality in feedlot holding ponds

	Mean level	Maximum level	Minimum level	No. of samples
Total nitrogen (mg/L)	220	1,095	25	175
Total Kjeldahl nitrogen (mg/L)	218	1,095	23	173
Ammonia nitrogen (mg/L)	89	670	0	99
Nitrate nitrogen (mg/L)	2.3	68.8	0	96
Nitrite nitrogen (mg/L)	0.5	5.1	0	20
Total phosphorus (mg/L)	71	387	2	171
Phosphate-P (mg/L)	17	133	0	102
Potassium (mg/L)	1,092	6,390	21	122
pH	8	10	7	135
Electrical Conductivity (dS/m)	7.8	37.8	1.0	187
Total dissolved solids (mg/L)	4,915	18,644	1,002	57
Calcium (mg/L)	126	597	13	114
Magnesium (mg/L)	118	805	2	114
Sodium (mg/L)	494	6,700	12	114
Sodium absorption ratio	7.1	65.8	0.5	119
Chloride (mg/L)	1,261	12,839	95	110
Sulphate (mg/L)	74	378	1	51
Total hardness (mg/L)	943	3,435	85	61
Total alkalinity (mg/L)	2,082	8,920	168	62
Aluminium (µg/L)	989	3,435	47	43
Boron (µg/L)	2,180	7,100	56	52
Copper (mg/L)	142	1,820	0	52
Total iron (mg/L)	24.1	110.0	0	50
Total manganese (mg/L)	2.9	46.0	0.2	42
Zinc (µg/L)	2,173	8,920	62	58

Microbial contaminants in liquid wastes

Runoff from beef cattle feedlots contains large populations of bacteria. Table 4.5 shows microbial analysis for *E. coli* and *E. enterococcus* for effluent sampled from holding ponds at three sites in southern Queensland immediately after runoff and seven days later. The heavy microbial load is significantly reduced by pond storage.

Table 4.5 Microbial analyses from Australian feedlot effluent samples showing rapid reduction in microbial load ('000 CFU) (Roser et al. 2011)

Sample ID and timing	*E. coli* ('000 CFU/100 mL)			*Enterococcus* ('000 CFU/100 mL)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
Feedlot 1						
– After runoff	18,600	8,000	26,000	104,000*	56,000	>200,000
– 7 days later	83	30	170	2,340	840	4,200
Feedlot 2						
– After runoff	12,700	4,900	22,000	50,000	44,000	60,000
– 7 days later	980	420	2,000	13,200	8,400	16,400
Feedlot 3						
– After runoff	2,160	200	4,600	2,167	1,040	2,820
– 7 days later	88	10	30	442	318	528

* assuming 200,000,000 CFU/mL is the upper value

Advanced effluent treatment

In response to changes in water availability and the cost of supply, the feedlot industry has expressed interest in treating and reusing effluent as part of the water supply for feedlots. There has also been interest in collecting biogas from holding ponds (see *Appendix 5. Advances in treatment of manure*).

Further reading

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BEEF CATTLE FEEDLOTS:
WASTE MANAGEMENT AND UTILISATION

5. Utilisation of manure, compost and effluent

CONTENTS

Nutrients added to utilisation areas are most efficiently removed from soils by growing high-yielding crops.

Grazing removes nutrients at a slow rate and is not a preferred land use for utilisation areas.

Select areas with good quality agricultural land.

Introduction

Feedlot manure, compost and effluent can be valuable sources of nutrients and organic matter for improving soil fertility, structure, water-holding capacity and crop or pasture production. Careful management is needed to gain the most benefit from their utilisation while protecting the environment and preventing impacts to neighbours.

While manure and compost may be spread off-site, effluent is less readily transportable and its utilisation generally occurs on-site.

Environmental protection for utilisation areas

Application of effluent and manure to land may pose a risk to the environment through

- excessive nutrients or nutrient imbalances in soils
- loss of nutrients to surface waters through runoff
- nutrient leaching through soils into groundwater.

The risk of nutrient loss from utilisation areas can be prevented or mitigated by selecting areas that provide suitable land and buffers to sensitive sites, by using appropriate spreading or irrigation practices, and by regularly monitoring soil nutrient levels and responding appropriately.

Amenity can be protected from odour and dust by careful application practices and timing of utilisation, and by maintaining adequate separation distances to nearby sensitive land uses.

Selecting a utilisation area

When selecting a new utilisation area or assessing the viability of an existing utilisation area, the following should be considered

- Nutrients are most efficiently removed by growing a high-yielding crop that is harvested and transported from the site. Thus the area should either be able to produce dryland crops reliably or should be irrigated.
- Select areas with good agricultural soils (e.g. adequate nutrients, plant available water capacity) with no serious limitations to plant growth (e.g. no subsoil constraints, not prone to salinity, waterlogging or flooding). The land should have a suitable topography for cropping (not steeply sloping).
- The utilisation area needs to be large enough to spread the nutrients in the wastes at sustainable levels. While it may be possible to use land with some significant limitations, this will require increased land area and/or management.
- Grazing removes nutrients at a slow rate and is not a preferred land use for utilisation areas. In addition, the recommended withholding period between effluent irrigation or manure spreading and grazing by stock is 21 days.
- Provide buffers between utilisation areas and watercourses, and unprotected aquifers (e.g. shallow water table covered by permeable soil).
- Provide adequate separation distances to nearby sensitive uses. Distance between utilisation areas and sensitive land uses such as residences and public amenity areas allows odour to disperse and reduces the likelihood of odour nuisance.

Management practices that protect the environment

Good management of manure spreading or irrigation is necessary to protect the environment. The following principles should be adopted

- Apply the wastes at rates that are sustainable considering the nutrients, salts and organic matter of the waste stream, soil nutrient status, land use and expected yields and climatic conditions of the site. Supplementary irrigation helps ensure the crops grow and fully utilise the applied effluent.
- Do not spread or irrigate wastes if the soil is very wet or if heavy rainfall is imminent. This may promote increased drainage or runoff which can pose a pollution risk to groundwater and surface water.
- Control the effluent irrigation rate to prevent runoff.
- Spread manure and effluent evenly.
- Incorporate spread manure into the soil to a shallow depth.
- Monitor soil conditions on an ongoing basis.
- Record nutrient application rates and nutrient removal rates. This helps in understanding the ongoing suitability of utilisation areas and the likelihood of nutrient losses.
- Protect amenity by careful application and timing of utilisation.

Uneven or uncontrolled effluent irrigation may pose a threat to the environment.

Nutrient budgeting

In determining a sustainable utilisation rate for any waste, take into account

- the concentration of nitrogen, phosphorus and potassium in the waste
- the removal rate of the crop that will be grown on the area (yield multiplied by nutrient concentration)
- the properties of the soils of the utilisation area including their capacity to store the nutrients
- allowable losses from the system.

The composition and yield of in-field crops will determine nutrient removal.

The mass balance equation is a useful principle to adopt when determining appropriate application rates for wastes. The mass balance equation is:

Applied nutrient ≤ (Nutrient in harvested produce + Nutrient safely stored in soil + Acceptable nutrient losses to external environment)

Table 5.1 shows typical nutrient analyses for types of manure from Australian feedlots. More detailed analyses are shown in Section 2.

Table 5.1 Typical nutrient composition of types of manure

Parameter	Pen	Aged	Compost
Dry matter (%)	74	63	74
Total nitrogen (% db)	2.5	2.2	2.1
Total phosphorus (% db)	1.0	0.8	1.3
Potassium (% db)	1.9	1.9	2.5
Sodium (% db)	0.3	0.3	0.4
Sulfur (% db)	0.4	0.5	0.5
Zinc (mg/kg db)	280	220	254

Sample and analyse manure to accurately calculate application rates.

Spreading 3–4 years' worth of nutrients at a time helps to ensure plant nutrient requirements are available when needed.

As samples can vary widely, the nutrient and dry matter content of the wastes should be tested just before the main spreading time. Similarly, crop yields and nutrient removal rates vary considerably. Historical yields for the farm or other farms in the district will provide a guide to the likely yield.

For practical and agronomic reasons it is often beneficial to apply several years of manure or compost nutrients at each spreading. Spreading at higher rates less frequently can help to spread wastes more evenly, overcome some nutrient availability challenges, minimise the need for regular soil disturbance that may damage soil structure, reduce the risk of causing nuisance for neighbours and minimise dissolved nutrient losses.

This strategy relies on storing some nutrients in the soil. The amount of nutrient that can be safely stored depends on the form of the nutrient and the physical and nutrient properties of the soil. For example, some soils can store large amounts of phosphorus that can be removed over several years. Where a particular nutrient is deficient, it is reasonable to build soil levels through applying waste; conversely, if soils have elevated nutrient levels, rates of waste application should be lower.

Since manure nutrients are not all available in the year of spreading, applying nutrients to last several years helps to meet plant needs. For example, one third of manure nitrogen may be available in year one, with 20–30% being available in year two (Wylie 2005). Applying three to four years' worth of manure initially will help to ensure there are enough nutrients for the plants.

Soils with high clay content usually have a high phosphorus sorption capacity.

Regardless of whether manure is applied annually or as one large application every few years, inorganic nitrogen and in many cases potassium will generally also need to be applied at some stage.

The following formula can be used to calculate the nutrient limited application rate (NLAR) of manure (t/ha) and effluent (kL/ha) and the sustainable annual application rate for manure or effluent.

$$NLAR = \frac{CR + SS + EL}{NW \times 10^{-3}}$$

Where

NLAR = nutrient limited application rate of feedlot manure (t/ha) or effluent kL/ha
CR = crop requirement for the applied nutrient (kg/ha)
SS = soil storage (kg/ha)
EL = allowable nutrient losses to the environment (kg/ha)
NW = available nutrient concentration in the feedlot manure (mg/kg) or effluent (mg/L)

Except for phosphorus, soil storage of nutrients is generally small and can be disregarded. The amount of phosphorus (kg/ha) that can be stored by the soil can be determined using phosphorus sorption analysis. ANZECC & ARMCANZ (2000) provides a method for estimating the environmentally-safe phosphorus storage capacity of the soil using the result of this analysis and the following formula

$$P = \frac{d \times P_b \times x/m}{100}$$

Where

P = phosphorus storage capacity (kg/ha)
d = profile depth (m)
P_b = soil bulk density (kg/m^3)
x/m = phosphorus sorbed per mass of soil (mg/kg) at 0.05 mg/L

The annual value for the soil storage (SS) variable in the NLAR equation can be determined based on the expected effective operational life of a feedlot in number (n) of years where

$$SS = \frac{P}{n}$$

Apart from nitrogen losses through ammonia volatilisation, allowable nutrient losses (EL) to the environment are also small and can be disregarded.

The NLAR equation assumes that manure or effluent is applied regularly. Under this scenario, the mineralisation rate does not need to be considered and it can be assumed that all of the applied nutrient is available every year. (For example, 60% of the nutrient applied this year would be available, along with say 30% of that applied the previous year and 10% of that applied the year before. Hence, the nutrient potentially available this year is 60% + 30% + 10% = 100%). Where manure is spread every few years, the mineralisation rate needs to be taken into account. In the case of effluent, almost all of the nutrients are in a readily available form so the mineralisation rate is not an issue.

Since plant nutrients in feedlot manure and effluent are not present in ratios that meet all of the needs of a growing crop, additional inorganic fertilisers are often applied to meet crop nutrient requirements. If mixed fertilisers are used it is important to consider the amounts of nutrients being applied in addition to those that are deficient.

In the example given on page 7, if manure is applied to satisfy the target potassium requirement there will be insufficient nitrogen for the crop. Consequently inorganic nitrogen would need to be added to optimise the crop yield.

Smaller feedlots generally spread manure on their own or nearby land.

Manure and compost spreading

Australian manure and compost utilisation practices

Most of the larger Australian feedlots send at least part of their manure off-site. The spreading rates used on-farm by these feedlots are highly variable, ranging from less than 5 t/ha to more than 30 t/ha. Manure is mainly spread on land used to grow hay, silage or grain crops (O'Keefe et al. 2011).

Most of the smaller feedlots spread manure on their own or nearby land, typically at rates of up to 5 t/ha.

An automatic weather station can help determine when conditions are suitable for manure and effluent utilisation.

Timing of manure and compost spreading

The ideal timing of manure applications depends on factors including

- crop or pasture needs
- manure or compost maturity
- timing of other management events (cultivation to incorporate manure)
- field conditions (soil moisture)
- wind conditions.

Avoid spreading manure under windy conditions.

Manure is often spread before planting but minimum till equipment does not incorporate it into the soil very well.

Withhold cattle from utilisation areas for at least 21 days after spreading.

In broadacre cropping, manure is generally spread before planting the crop and incorporated with the cultivation associated with the seeder pass.

On soils with low background nutrient levels, spreading manure just before sowing may result in crops that are less vigorous and lower yielding than those grown using inorganic fertilisers. This can occur because the nutrients in the manure are less available for immediate uptake by the plant roots. Nitrogen and phosphorus are present in manure and compost in both inorganic and organic forms; the latter have to be mineralised into inorganic forms to be available to the plants. Most potassium in manure is in the inorganic form and ready for uptake.

Applying manure 4–6 months before the crop is established allows nutrients to mineralise from their organic matter and reduces the risk of nitrogen draw-down, which may occur after aged manure is spread. However, nitrogen losses can increase if manure is applied too far ahead of crop planting, particularly if there is minimal incorporation of the manure. Nutrient availability is likely to be less of a concern if the manure is well-aged or composted before spreading, particularly if the soil has reasonable background nutrient levels.

Accessibility of manure nutrients to plant roots can also be an issue. In modern broadacre cropping systems, manure is generally broadcast before the crop is sown using low disturbance, no till (e.g. knife points and press wheels) or zero till (e.g. disc seed systems) seeding equipment. This results in little incorporation of manure at planting and minimal manure in the seed row close to the tiny roots of germinating crop seedlings. Minimal manure incorporation can also result in increased nitrogen losses. Thus spreading manure as close as possible to planting is sometimes recommended to allow the crop to take up rapidly mineralised nitrogen as it becomes available. In many cases poor crop vigour is phosphorus-related.

The problems described above can be overcome by spreading manure annually or using a ‘starter’ application of inorganic phosphorus fertiliser with the manure just before planting. Depending on the background phosphorus levels in the soil, the fertiliser rates may be significantly lower than conventional application rates. The levels of available nutrients in paddocks planned for manure or compost spreading should be tested. Recent improvements in soil testing technologies such as DGT (Diffuse Gradients in Thin Films) tests have increased confidence in making decisions on whether inorganic fertiliser should be applied in conjunction with manure applications.

If the paddocks are to be ploughed for sowing, spreading manure beforehand will allow it to be incorporated into the soil. If possible manure should be spread when the soil is not too wet to limit compaction.

Manure spreading should be avoided under windy conditions especially if the wind is blowing towards nearby houses or public use areas.

To protect grazing livestock from risk of pathogens a withholding period of 21 days applies to paddocks that have been spread with manure or compost.

Manure and crop requirement

The crop requirement (CR) depends on the yield and nutrient content of the crop grown. If the utilisation area is used to grow an oat hay crop with a dry matter yield of 7 t/ha and a nutrient content of 2% nitrogen, 0.2% phosphorus and 1.4% potassium, the CR will be 140 kg N/ha, 14 kg P/ha and 98 kg K/ha.

If the soil of the utilisation area has a depth of 0.6 m, a bulk density of 1,400 kg/m^3 and can adsorb 200 g P/kg, the total soil storage (SS) capacity is1,680 kg of phosphorus. If the expected life of the feedlot is 30 years, the annualised SS is 56 kg P/ha.

The mass of nitrogen, phosphorus and potassium in each tonne of manure for spreading can be calculated from nutrient and dry matter analysis results.

The allowable loss (EL) of nitrogen might be 20 kg N/ha/yr.

In this example, the average nutrient concentrations for aged manure presented in Table 5.1 are used as the available nutrient concentration (NW). With a dry matter content of 63%, each tonne of aged manure contains 630 kg of dry matter with 2.2% nitrogen, 0.8% phosphorus and 1.9% potassium. Multiplying the dry matter mass (630 kg) by the nutrient concentration (%) provides kilograms of nutrients in each tonne of manure. In this case, each tonne of manure contains 13.8 kg of nitrogen, 5.0 kg of phosphorus and 12.0 kg of potassium.

Applying the NLAR formula for nitrogen:

$$\text{NLAR (t/ha)} = \frac{140\text{ kg} + 0 + 20}{13.8}$$

$$\text{NLAR (t/ha)} = 11.6\text{ t/ha}$$

Applying the NLAR formula for phosphorus:

$$\text{NLAR (t/ha)} = \frac{14\text{ kg} + 56 + 0}{5.0}$$

$$\text{NLAR (t/ha)} = 14.0\text{ t/ha}$$

Applying the NLAR formula for potassium:

$$\text{NLAR (t/ha)} = \frac{98\text{ kg} + 0 + 0}{12.0}$$

$$\text{NLAR (t/ha)} = 8.2\text{ t/ha}$$

On this basis, potassium is the limiting nutrient, and the sustainable annual spreading rate is 8.2 t/ha/yr for an oat hay crop yielding 7 t/ha.

Manure and compost spreaders

There is a wide range of manure spreaders. The amount of manure for spreading, the quality of the manure and the proposed spreading rate all determine which spreader will be most suitable. The cost and efficiency of manure spreading influences the value of manure as a fertiliser.

Manure should be tested just before the main utilisation period.

Balance the nutrients added to the crop and soil requirement.

A horizontal beater manure spreader

Spinning disc spreader

Features to consider when selecting a spreader include

- *Spreading pattern and width* – some spreaders have an effective spreading width of 2 m while some of the specialised European manure spreaders spread up to 10 m. A greater spreading width reduces soil compaction.
- *Horizontal versus vertical beaters* – horizontal beaters usually spread only about the width of the spreader whereas vertically mounted beaters generally spread over a larger area with each pass. Beaters are essential for spreading unscreened lumpy or high moisture manure as they break up the lumps.
- *Conveyor belt versus moving-floor chains* – manure can be moved to the back of the spreader using a conveyor belt or a chain and slats. These can be hydraulic or PTO driven. Conveyor belts wear more rapidly than the chains. Floor chains are better when spreading unscreened or high moisture manure and tend to have fewer problems with manure bridging.
- *Beater/spinner design* – the rotation speed of the beaters will affect the width of spread and application rate. Generally the greater the height of the spinner or beater above the ground the greater the width of spread, but a high centre of gravity can result in instability on uneven ground.
- *Spreader power requirements* – check the power requirements of the spreader in relation to the tractor or truck.
- *Application rate* – most spreaders need a minimum application rate of about 5 t/ha to get an even spread and this may be higher for some spreaders. Fresh lumpy manure does not spread well and is likely to be uneven at rates of less than 10 t/ha.
- *Load capacity* – larger capacity spreaders offer better efficiency by minimising time between loads. Spreader capacity ranges from under 3 m^3 to 15–30 m^3 models. Some spreaders can be fitted with extension sides ('hungry boards') to increase capacity.
- *Design of sides* – vertical sides are preferable to angled sides as these are less likely to result in manure 'bridging'.
- *Engineering* – under-engineered spreaders may require increased maintenance (e.g. due to bearing failures, bent shafts) compared to those with more robust engineering.

Purpose-built manure spreaders are typically categorised as rear or side discharge systems with capacities of 1–20 t. Rear discharge spreaders are usually equipped with a moving conveyor belt, moving floor chain or hydraulic push door that transfers manure to horizontal or vertical beaters, or spinning discs. Side discharge systems use a horizontal auger to transfer manure to the spinning discs or beaters. Both discharge systems can be self-propelled (i.e. mounted on a truck or tractor chassis) or towed behind a tractor as an independent unit.

Conventional fertiliser spreaders typically use a rear door to control the rate of fertiliser falling onto the spinning discs (to ensure accurate, uniform application rates). Chunks of manure can become trapped in the rear door and prevent manure from being uniformly spread over land. Hence, conventional fertiliser spreaders are not suited to applying unscreened manure.

The best coverage is often achieved by belt or moving floor-fed horizontal disc spinners with screened or composted manure. Belt-fed spreaders are less effective with inconsistent manure. While side-delivery spreaders use more power, they are suitable for all manure. Horizontal beater spreaders also suit all manure but spread at higher rates.

The uniformity and time efficiency of manure application is highly dependent on manure physical properties. Manure with a low moisture content (<35% moisture) that has been either composted and/or screened can be effectively applied using a spreader with either beaters or spinning discs but inconsistent, lumpy manure can be effectively applied only using a spreader with beaters.

Operator efficiency influences where manure is spread on the paddock and at what rate. This is especially relevant for spreaders where operation speed influences the rate applied. Consistent spacings between spreader passes are important for covering the whole paddock evenly. GPS guidance aids the accuracy and efficiency of the spreading operation, reducing overlap and missed areas, compared to estimation by the operator.

Most spreaders need a minimum rate of 5 t/ha for even spreading.

Off-site use of manure and compost

Many feedlots provide at least part of their manure or compost to off-site buyers. *Appendix 3: Duty of care: manure utilisation* can be provided to people buying manure to ensure they are aware of their duty of care.

Appendix 4: Manure valuation pro forma provides a valuation method using fertiliser price and manure nutrient content to place a value on manure.

Manure transport

To avoid manure spillage and associated odour or dust concerns, loads of manure being transported along public roads should always be covered.

Operator efficiency influences how evenly manure is spread and at what rate.

Utilisation of carcase compost

The principles for utilising carcase compost are generally the same as those for manure or compost. Since carcase compost contains material of animal origin, it should not be spread on land that is being grazed.

Travelling spray irrigator

High-pressure spray irrigation of effluent can generate odours and aerosols.

Well-designed flood irrigation reduces aerosols but must not create run-off of effluent.

Effluent irrigation

Australian effluent utilisation practices

Most larger feedlots irrigate some effluent, generally using spray irrigation systems; some use surface irrigation. Effluent is mostly used to grow hay or silage crops although it is also used to produce grain.

Timing of effluent irrigation

The timing of effluent irrigation will often be driven by the need to empty effluent ponds so that they are ready to receive future runoff. To reduce pathogen levels, effluent should be stored in the holding pond for at least a month before irrigating and then used to meet crop water demands like other irrigation. If a terminal pond is used to capture runoff from an effluent irrigation area this water should be irrigated back onto the land as soon as practical after any significant inflow.

Effluent applications should never raise the soil moisture content above field capacity and the application rate must be controlled to ensure runoff does not occur. Effluent should not be irrigated under heavy cloud, if rain is forecast or on windy days.

Effluent should not be irrigated in the four weeks before harvest on human food crops that will be eaten raw or with minimal processing. To protect grazing livestock from pathogen risks, a withholding period of 21 days after effluent irrigation is recommended.

Practical effluent irrigation

A range of different effluent irrigation methods is available. The most suitable methods will depend on the following factors

- effluent composition
- topography – slope and uniformity
- crop type – cultivation requirements, value, required accuracy and uniformity of application
- soils – permeability, sealing characteristics, water holding capacity, variability
- costs – capital, labour and energy
- physical shape of the utilisation area – fences, drainage lines, other infrastructure
- prevailing seasonal conditions.

The salt content of effluent may be a constraint and cause leaf burn, yield reduction and degradation of some soils and crop types. Sustainable effluent irrigation rates may need to be very low to manage the salt load. Management options could include using a low pressure spray or drip system, effluent dilution with clean water, or following effluent with irrigation with clean water.

Some form of sprinkler irrigation is generally preferred to flood irrigation because

- there is reduced potential for runoff and subsequent collection problems
- it can provide greater uniformity of application
- it can be used on soils with high infiltration rates (e.g. >10 mm/hr)
- it can accurately apply smaller quantities more regularly to more closely balance crop or pasture water requirements and utilise more effluent.

Travelling drip irrigation may also be an option.

Small travelling irrigators generally operate at higher pressures to pivot and lateral move irrigators which means a higher operating cost per unit of water applied.

For irrigation of resuspended sludge or other effluent with a high solids concentration system, the irrigation system requires high-pressure main lines to prevent settling in the pipeline, capacity for clean water flushing along the pipeline and large aperture spray nozzles.

Table 5.2 compares effluent irrigation methods.

Travelling drip irrigators can apply effluent evenly at low rates.

Table 5.2 Comparison of irrigation methods

Irrigation method	Typical area range (ha)	Typical operating pressures (kPa)	Site slope limitations	Typical application rates (mm/hr)	Comparative costs			Uniformity of application
					Capital	Labour	Energy	
Sprinkler								
Handshift	<10	200–400	<10%	3–10	low	very high	medium	high
Powered side toll	20–50	200–400	<3%	3–10	medium	medium	medium	high
Travelling irrigator	8–50	400–650	<7%	5–25	medium	high	high	medium/ high
Centre pivot	40–100	100–300	<2%	variable	high	low	low	very high
Lateral move	50–200	100–300	<2%	variable	high	low	low	very high
Surface Systems								
Border check	–	10–50	0.1–1.0%	5–10	low	medium	-	low
Contour ditch	–	10–50	1.0–7.0%	5–10	low	medium	-	low
Furrow	–	10–50	0.05–1.0%	5–10	medium	high	-	medium
Gated pipe /layflat fluming	–	10–100	0.05–1.0%	5–10	medium	high	-	medium

Source: Skerman 2000 adapted from Lott and Skerman 1995

In some cases, terminal ponds may be positioned below utilisation areas to capture the initial and possibly heavily polluted runoff from storm events and runoff from flood irrigation. Captured runoff should be re-irrigated onto the utilisation area when the soil has a suitable moisture content.

Further reading

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Appendix 1.

Standard operating procedures for waste management and utilisation

This appendix provides suggested standard operating procedures for feedlot manure, compost and effluent management and utilisation that could be incorporated into a feedlot quality assurance system.

CONTENTS

Manure and effluent management procedures

1. Pen cleaning/manure removal

- Pens are cleaned regularly at intervals of 13 weeks or less.
- Pens are best cleaned when the manure is moist but not wet. However, they have to be cleaned regularly regardless of the manure moisture content.
- Manure is first removed from under fencelines, around water troughs, shade posts, and along and behind the aprons using a bobcat, under-fence pusher, slider blade or other equipment.
- Manure is then scraped from the pen surface into a mound. If an interface layer is to be retained, great care is taken with depth control. The depth to the interface layer is determined by pushing a screwdriver through the manure pad and noting the depth at the change in resistance at the interface layer. Box scrapers and graders provide good depth control and often are the best equipment for retaining an interface layer. If the manure will be removed down to the gravel pad, a wheel loader or excavator can also be used. Under wet conditions, an excavator may be useful.
- Generally the manure will be removed promptly either to the manure stockpiling/composting area or off-site. A front-end loader is used to transfer the mounded manure to a truck or trucks (using two trucks will minimise downtime while the manure is transported). The trucks are best parked within the pen close to the mound for loading, but otherwise along the bottom fenceline.
- Under some circumstances, a mound will be retained in the pen, but can be formed successfully only from manure that is moist. The manure also needs to be compacted so that it is not dispersed by the cattle. Mounds need to be shaped so they shed runoff, and located so that they do not interfere with pen drainage. In unshaded pens, they should be situated in the centre of the pen with their long axis running down the slope. In pens with shade, they should be located downslope of the shade structure.
- Any potholes or depressions in the pad are repaired (see Procedure 3).

2. Under-fence cleaning

- Under-fence cleaning is done at every pen cleaning, but also between pen cleanings as needed to remove accumulated manure that will obstruct pen drainage. This is particularly important for manure that has accumulated under the fenceline at the bottom of the pen.
- Manure is moved from under the fencelines into the pen and is collected during pen scraping/cleaning operations. Alternatively, it is taken immediately to the manure stockpiling/composting area. It should never be left in the drains.

3. Elimination of wet patches and potholes in the pens

- Pens are inspected after rainfall and any wet patches or potholes are repaired or noted for repair at the next pen cleaning.
- Any wet or loose material is removed before the pothole or depression is backfilled with moist gravel. This material is rolled and compacted to ensure the pen surface retains a smooth uniform slope.
- At the same time, water troughs are checked for leaks. Any leaks detected are repaired promptly.

4. Removal of feed residues from feed bunks

- Feed residues are removed from feed bunks on a daily basis.
- Spoilt or wet feed is removed from the bunks using a shovel or brush. The material is either thrown into the pen area for removal during pen cleaning operations or is taken straight to the manure stockpiling/composting area.

5. Water trough cleaning

- Water troughs are cleaned at least once a week.
- Troughs are cleaned by
  - checking for any leakages
  - turning off the water supply tap to the trough
  - removing the bung and draining half of the water from the trough, then replacing the bung
  - scrubbing any algal growth and other foreign matter from the sides and bottom of the trough

- removing the bung and draining the remaining water and foreign material from the trough
- replacing the bung and turning the water supply tap back on
- checking the trough has refilled with clean water.

6. Drain and sedimentation device cleaning and maintenance

- Generally drains should be free of vegetation. Where drains or diversion banks need to be vegetated, the grass should be kept short by regular mowing or slashing.
- Following runoff events, the level of the settled sediment in the drains and sedimentation device is checked. Excess sediment is allowed to dry before being removed.
- The drains and sedimentation device are cleaned using a box-scraper, bobcat, slider blade, front-end loader or an excavator working from the bank. Sediment is removed from the device and the weir and transported to the manure stockpiling/composting area.
- The drains and sedimentation device are checked to confirm that they have a smooth, uniform slope.
- Any potholes or low areas in the floor or walls of the sedimentation device or drains are backfilled and compacted to produce a durable surface.

7. Horse stables bedding management

- The base of the horse stables is bedded with suitable material e.g. sand or sawdust. The bedding is frequently and regularly removed and replaced to ensure dry, low-odour conditions. Removed material is taken to the feedlot manure stockpiling or composting area.
- The bases of the run-out areas are inspected at least quarterly and maintained as needed.

8. Effluent holding pond maintenance

- Following rainfall runoff, the water level in the effluent holding pond is checked.
- Ideally, the effluent is stored within the holding pond for a month to reduce the pathogen load before being irrigated. However, when the effluent level reaches within 1,500 mm of the embankment crest, it is irrigated provided soil moisture and weather conditions are suitable. The effluent is managed to maintain a minimum of 600 mm of freeboard on the holding pond.
- A depth of at least 300 mm of effluent is maintained in the bottom of the holding pond after irrigations.
- The weirs are routinely checked after runoff events to ensure they are clean and operating properly. The pond walls are inspected regularly to assess their structural integrity, and any signs of problems with either the weirs or the pond walls reported to management for prompt action.
- The depth of sludge in the holding ponds is monitored. When sludge begins to compromise effluent storage capacity (e.g. more than 20% accumulation, typically every 5–20 years), it is carefully removed using a dragline, agitator and pump or excavator. Removed sludge is either spread directly onto land or is taken to the manure storage/composting area for drying before being added to the manure or compost windrows.

9. Manure stockpiling and stockpile management

- Manure is formed into windrows for aging. The windrows are long, low piles with a triangular cross-section, a base width of 3–4 m and a height of 1.5–2 m.
- The windrows are oriented with the long axes perpendicular to the contours of the area to promote free drainage around the manure piles.
- After the manure has been aged for at least six months in a windrow, it can be screened before being utilised or transferred to a stockpile for storage.
- Wet manure or sludge is never added directly to a large manure stockpile. Wet manure solids are formed into low windrows and allowed to dry first. Turning the windrows promotes more rapid drying.

10. Managing fires in manure stockpiles

- Manure fires are difficult to distinguish and can burn for many months, releasing acrid odour and smoke. Manure stockpiles are checked for fires on a daily basis so that action can be taken quickly.

- Except for very small fires, expert advice and assistance on fire extinguishment should be sought.
- If there is a very small fire in the stockpile, ignited particles can be removed with appropriate machinery (e.g. front-end loader) but *only* if this can be done safely. The ignited particles are then extinguished with water or allowed to burn out.
- In the event of a manure stockpile fire, details of the event and actions taken are recorded. If the cause of the fire can be identified, this is also recorded and manure management practices modified to prevent a reoccurrence.

11. Manure stockpile area maintenance

- The base and banks surrounding the manure stockpiling/composting area are checked at least quarterly but also after heavy rainfall; the area is maintained as necessary.
- Any potholes or low areas in the base or bank, or bank weaknesses, are backfilled and compacted to produce a durable surface.

12. Delivery of co-composting materials

- Co-composting materials include any solid matter that will be composted with the manure. These are unloaded on a suitable area within the manure stockpiling/composting pad. If these are not to be immediately mixed with manure, they are formed into windrows with a base width of 3–4 m, 1.5–2 m high with a narrow top and sloping sides.
- Details of the delivery date, type and quantity of material delivered are recorded.

13. Compost management

- Manure and any co-composting materials are thoroughly mixed and formed into windrows with a triangular cross-section. These are 3-4 m wide at the base and 1.5–2 m high.
- The moisture content of the composting material is tested. At the ideal moisture content, the compost appears moist and little moisture can be squeezed from a handful. If the material is too dry, water or effluent can be added using the turning equipment, high-pressure jets or micro-sprinklers. Care is taken to ensure leachate is not produced. If the material is too wet, it can be turned every day or two to promote drying.
- After the windrows are formed, the core temperature and moisture content of the composting material are monitored at least weekly. The results are recorded separately for each windrow.
- The temperature is monitored by inserting a long probe thermometer deep into ten separate spots along the length of the windrow. Alternatively, a thermistor string can be used.
- Moisture is monitored by taking a handful of compost from an arm-length depth at ten sites along the windrow. The compost is classed as ‘dry’ if it appears dry and no water is released when the handful is squeezed, ‘wet’ if it has water leaching from it without being squeezed, or ‘moist’ if it appears wet but little moisture comes out when squeezed. ‘Moist’ is the ideal moisture content.
- If water is available, material that is ‘dry’ is watered before turning. Effluent is not used to water windrows after initial windrow formation. Care is taken to ensure the material does not become waterlogged and to avoid excess pooling of water around the compost piles.
- If material is ‘wet’, the windrows are turned more frequently (every couple of days) and/ or dry co-composting materials incorporated into the pile.
- The compost pile is turned after high temperatures (>55°C) are maintained for at least three consecutive days. The material is turned at least three times after three days of high temperatures during the active phase. Fortnightly turning is suggested but turning can occur more frequently if the pile has heated sufficiently and equipment and labour are available.
- The active phase is considered complete when the pile no longer heats up above 55°C after turning. After completion of the active phase, the compost can be kept in a windrow or formed into a stockpile where it is allowed to cure for at least a month.
- Details are recorded of
  - the date each windrow was formed
  - the materials added
  - results of temperature and moisture content tests
  - turning and watering
  - date active phase is considered complete
  - quantity of compost removed from site.

Mortalities management procedures

14. Mortalities composting

- Mortalities are promptly transferred to the composting area using equipment that is not used for feed processing. Mortalities are lifted and carried from the pens, not dragged. This is particularly important for infected mortalities.
- Using a front-end loader bucket, spread a 60 cm deep base of absorptive material (e.g. sawdust or waste straw) that will retain fluids released during decomposition. The base should be about 5–5.5 m wide as this will allow two mortalities to be laid side-by-side. If mortalities will be stacked two high, the width should be increased to 7 m. Allow at least 2.5 m of windrow length for each tonne of mortalities.
- Generally, the thoracic cavity will be opened or the rumen punctured. However, this should not be done if the likely cause of death is a zoonosis or infectious disease.
- Mortalities are placed in a single layer on top of the absorptive layer. If the windrow will be two carcases wide, the spines of the animals are placed in the centre of the pile with the legs on the outer edges.
- The bodies are covered completely with at least 0.6 m of sawdust or manure. A second layer of mortalities can be placed on top with a further 0.6 m of cover material over it. Ideally the cover material will have a moisture content of about 50-60% wet basis. Material with this moisture content will feel moist but it should not be possible to squeeze moisture from a handful of it. If necessary, wet the material with water or effluent.
- Mortality coverage and windrow core temperatures need to be monitored weekly during the active stage.
- Using a long-stemmed thermometer, measure the core temperatures at 10 spots along the windrow. Alternatively, a thermistor string can be used. Temperatures of 50–60°C should be reached within 2–3 days of pile commencement and remain high for at least two weeks.
- Turning of the carcase windrow is recommended only after the organic material has broken down into small particles and the bones partially softened (typically 4–6 months). Turning and watering (if required) is recommended at this stage.
- The active stage is completed when the pile no longer heats after turning. The material will be a dark brown to black humus-like material. Turning is suggested at this point.
- Curing can then occur. Allow a total of 12 months for active composting and curing. To prevent regrowth of pathogens, composted material must be kept separate from uncured material.
- The finished material is screened before spreading to remove remaining bones.

15. Disposal of mass mortalities by composting

In the case of an excessive number of cattle deaths (any substantial increase in cattle mortalities)

- Contact a veterinarian to undertake post mortems.
- Report the mortalities to the relevant environment protection agency and to ALFA who will notify the Chief Veterinary Officer.
- If composting is deemed an appropriate disposal method, follow the previous procedure but take additional precautions if an infectious disease is the possible cause. Do not puncture the rumen or open the body. To achieve high temperatures that are able to kill pathogens as quickly as possible, use a 15–30 cm layer of silage or moist manure then a layer of ground straw as the cover material. Maintaining a good level of cover is crucial. Do not turn the pile during carcase decomposition. Do not excavate or spread compost until approved by the Chief Veterinary Officer. Dispose or use the compost in a manner approved by the Chief Veterinary Officer.
- Where the livestock deaths are not the result of disease, dry porous materials that do not necessarily produce high temperatures quickly can be used as cover material. The pile can be turned after 60–90 days, although this may not be necessary. Excavation and spreading of compost can occur once the soft tissues and internal organs are fully decayed (usually 8–12 months after starting the process) and curing has occurred.
- In many circumstances, the compost will be deemed safe to spread and can be screened first to remove remaining bones.
- In other circumstances, the compost will need to be buried or burnt.

Effluent irrigation procedures

16. Selection of effluent irrigation area

- When effluent needs to be irrigated, an appropriate utilisation area is selected. This is an area that has not yet received its annual effluent application rate. Areas that are known to have elevated nutrient levels are not to be selected.
- The wind speed and direction is checked to ensure the prevailing wind direction will not carry odours directly towards nearby residences or other receptors. If this is likely, an alternative area may be selected or irrigation delayed.

17. Effluent irrigation

- The weather forecast and the moisture content of the soil are checked. Effluent is irrigated only when the soil is sufficiently dry to absorb the applied liquid and should not occur within 48 hours of heavy rain. Do not irrigate if significant rainfall is expected.
- Plan to irrigate effluent from mid-morning to early afternoon when good odour dispersion is likely. Avoid effluent irrigation from mid-afternoon to evening or just before weekends or public holidays, particularly if close to a public area.
- A suitable rate of effluent irrigation is determined based on the nitrogen, phosphorus and potassium content of the effluent.
- The soil is monitored during irrigation to ensure there is no surface pooling or effluent runoff.
- Staff are advised of the risks associated with effluent irrigation and the appropriate personal protection equipment to use. This may include high quality (P2) face masks, overalls and disposable gloves.
- The irrigation system is set up to apply effluent at the target rate.
- If a travelling irrigator is used, it is checked every two to three hours to ensure it is moving in the correct direction and not creating other issues.
- Details of the following are recorded:
  - date of irrigation
  - weather forecast summary, including wind direction and rainfall
  - assessment of likelihood of amenity impacts
  - utilisation area (name of paddock)
  - target and actual rate of application (mm).

Manure utilisation procedures

18. Selection of manure spreading area

- A suitable area is selected for manure utilisation. This will exclude areas that have already had their annual allocation of manure applied or that are showing elevated nutrient levels.
- The wind speed and direction is checked to ensure the prevailing wind direction is not directly towards nearby residences or other receptors.
- Staff are advised of the risks associated with manure spreading and the appropriate personal protection equipment to use. This may include high quality (P2) dust masks, overalls and disposable gloves.

19. Manure spreader calibration

- Use plastic drop sheets or tarpaulins of at least 2 m × 2 m.
- These drop sheets are laid on the ground in the path of the spreader (some near the centre, some on the outside so that two side-by-side passes will run over the sheets).
- For each drop sheet, place a 1 m × 1 m wire square over the drop sheet.
- The spreader is passed over the sheets in two side-by-side runs at the usual operating speed.
- Weigh the manure collected from each of the wire squares.
- The weight of manure landing in each wire square (kg/m^2) is multiplied by 10 to convert it to a rate in tonnes per hectare.
- The spreader is adjusted if necessary, and the exercise repeated until the spreader is operating at the target rate.

20. Manure spreading

- Check the weather before undertaking manure spreading. Do not spread if heavy rain is expected or if it has fallen over the last 48 hours.
- A suitable manure spreading rate is determined based on the nitrogen,

phosphorus and potassium content of the manure, soil properties and the intended land use of the utilisation area. The rate should be consistent with the ability of soils and plants grown on the area to sustainably use the applied nutrients, salts and carbon in the manure or compost.

- Plan to spread manure from mid-morning to early afternoon when good odour dispersion is likely. Avoid spreading from mid-afternoon to evening. Avoid spreading manure just before weekends or public holidays, particularly if close to a public area.
- Calibrate the manure spreader to ensure it is spreading at the target rate.
- Record the following details
  - date of manure spreading
  - weather forecast summary, including rainfall and wind direction
  - assessment of likelihood of amenity impacts
  - area of application (name of paddock)
  - target and actual rate of application as t/ha.

21. Transport of aged manure and compost

- To minimise the risk of material spillage during transport, loads do not exceed vehicle capacity.
- The load is covered to minimise dust and odour emissions during transport along public roads.
- Where practical, avoid transport routes that have a large number of houses or public use areas close to the road.

22. Manure and compost removal from the site

- When manure or compost are removed from the feedlot site, the following details are recorded
  - the date, quantity and type of waste removed
  - the name of the transporter and/or operator that removed the wastes
  - the intended use of the wastes
  - the destination of the wastes (including the property owner's name and address).
- The recipient of the manure or compost is provided with a 'Duty of Care: Manure Utilisation' sheet.

Procedures following heavy rain

Also refer to the following procedures:

6. Drain and sedimentation device cleaning and maintenance

8. Effluent holding pond maintenance

9. Manure stockpiling and stockpile management

11. Manure stockpile area maintenance

23. Diversion banks and drains

- All diversion banks, drains and bunds are checked to ensure extraneous stormwater runoff cannot enter the controlled drainage area of the feedlot and the manure stockpiling/composting areas.
- Any damage to banks, drains and bunds is immediately repaired and details of the maintenance recorded.

24. Manure stockpiling/composting area

- The manure stockpiling/composting areas are checked to ensure they are freely draining.
- The layout of the manure or compost pile(s) is checked to ensure they are not blocking runoff and promoting pooling of water. When conditions allow, reconfigure any piles that are impeding drainage.
- The base of the manure stockpiling/composting area is checked for potholes and other low spots. If necessary, the base is repaired when conditions permit.
- Details of any maintenance procedures undertaken are recorded.

On-going procedures

25. Fly and vermin management

- Fly and vermin levels around the feedlot are monitored on an ongoing basis.
- Vermin baits are used and/or replaced as required.
- Bait stations are checked on a weekly basis.

26. Dust management

- Dust levels are monitored on an ongoing basis.
- Internal roads are watered as required to reduce dust.

- Where practical, stocking density in pens is increased (to within licence limits).
- Where water is available, dry manure in compost piles is watered before and during turning to suppress dust.

27. Operational recording

- Record details of all cattle introduced to and removed from the premises, including
  - number and live weight of cattle in each pen
  - date of introduction/removal
  - sickness or deaths of animals.
- Record details of routine operating procedures undertaken to prevent or minimise environmental harm, including
  - spilt feed cleaning
  - wet patch elimination
  - repairs to potholes
  - under-fence cleaning
  - pen cleaning and manure removal, storage and utilisation
  - effluent irrigation
  - fly and insect treatment and control
  - maintenance of the controlled drainage area confining the feedlot complex.
- Record details of maintenance works carried out, including
  - drainage channel maintenance
  - diversion bank and dam wall maintenance
  - sedimentation system maintenance
  - maintenance of banks within utilisation areas
  - holding pond maintenance.
- Record details of likely environmental impacts resulting from releases of contaminants into the environment.
- Record details of staff training to enhance environmental management skills and awareness of environmental issues.
- Record details of off-site movements of wastes including the following
  - date, quantity and type of wastes removed
  - name of the transporter and/or operator that removed the wastes
  - intended use of the wastes
  - destination of the wastes (including the property owner's name and address).

28. Staff training

- All staff members are trained to know their responsibilities in regard to environmental management.
- All staff members are trained in procedures applicable to their role.
- Staff members are provided with relevant technical information for reading.
- All staff members are made aware that
  - manure, particularly pen manure, contains pathogens that may cause illnesses
  - fine dust appears to pose the greatest risk
  - health risks can be minimised by adopting good hygiene practices. Always wash hands well after handling manure, compost, effluent or mortalities, especially before touching food, eating utensils, cups, your eyes or other people
  - personal protective clothing and equipment including high quality (P2) dust masks, overalls and disposable gloves provide additional protection.
- Staff members are provided with additional on-the-job training and also participate in appropriate environmental courses, seminars or workshops.

Environmental monitoring and reporting procedures

29. Environmental monitoring

- Throughout the year, environmental monitoring occurs in accordance with licence or permit requirements.
- Aged manure and/or compost are analysed at least annually before the main spreading season.
- If effluent is irrigated or used to moisten materials before composting, it is analysed at least annually, ideally just before the main usage period.
- If effluent or manure/compost are utilised on-farm, the soils of the utilisation area(s) are analysed at least annually (in the years that they are irrigated with effluent or spread with manure or compost).

- Monitoring equipment, analysis request forms and a supply of monitoring containers and sampling bags are kept on hand.

30. Annual environmental report

- An annual environmental report is prepared that includes
  - summary of pen cleaning
  - soil analysis results for samples taken from any on-farm utilisation area where effluent or manure has been spread in the reporting year
  - analysis results for effluent for irrigation and aged and/or composted manure from the stockpile area
  - summary of the effluent irrigation rate (mm) to each paddock, along with an estimate of the nitrogen, phosphorus and potassium application rate
  - summary of the manure and/or compost spreading rate on each paddock, along with an estimate of the nitrogen, phosphorus and potassium application rate (kg/ha)
  - type of crop, pasture or forage grown on each utilisation area along with an estimate of the harvested yield and the estimated nitrogen, phosphorus and potassium removal rate (kg/ha)
  - records of any manure and/or compost provided to off-site users including the date of the transfer; the name and contact details of the recipient; and the type and amount of material supplied
  - details of any complaints received, communications with the complainant, investigations into the cause of the complaint, any corrective actions taken and any changes to procedures
  - details of any environmental incidents and any associated corrective actions and reporting.

Complaint and incident management procedures

31. Community consultation

- Maintaining open lines of communication with the public is important in dealing with amenity or other issues.
- During feedlot operating hours, a telephone complaints line is operated for the purpose of receiving any complaints in relation to activities conducted at the premises.
- All neighbours are encouraged to make contact if they have any issues or any complaints concerning the feedlot or the manure and effluent utilisation practices.
- Feedlot management informs immediate neighbours of proposed effluent irrigations and manure/compost spreading events or any unusual activities that may result in nuisance.
- Any corrective actions taken in response to a complaint are reported back to the complainant. The complainant is consulted about whether this has eliminated or reduced the source of the complaint.

32. Complaint recording

- Details of all complaints are recorded. These include
  - time and date of complaint/incident
  - method of communication (telephone, fax, email, letter, personal visit)
  - name, address and contact telephone number of complainant (Note: if complainant does not wish to be identified, record as ‘Not Identified’)
  - wind direction and strength and any other relevant climatic conditions
  - nature of the complaint
  - any management practices that may have contributed to the complaint
  - name of person responsible for investigating the complaint
  - action taken in relation to the complaint and signature of responsible person
  - details of any further communications with the complainant
  - details of notification of the Administrating Authority (if applicable).

33. Incident recording

- Full details of all environmental incidents are recorded, including the following
  - time, date and duration of equipment malfunctions or other operational problems that may have resulted in a direct or indirect impact on the environment
  - any preventative or corrective action implemented
  - any uncontrolled release of contaminants reasonably likely to cause environmental harm
  - any emergency involving the release of contaminants reasonably likely to cause material or serious environmental harm including effluent holding pond overflows

  - any substantial increase in livestock mortalities
  - any change in management practices which may have resulted in enhanced environmental performance.
- Relevant authorities are notified of any incident reasonably likely to cause environmental impacts, in accordance with licence conditions.

Sample record sheets

- The Complaints Register and the Environmental Data Record are useful environmental management records for feedlots.
- The Complaints Register is used to record details of complaints made by the general public in relation to impacts to community amenity.
- The Environmental Data Record is used to record any items of concern noted during ad hoc or subjective assessments by feedlot staff, as well as any actions taken and the effectiveness of those actions, and any items of concern noted during monitoring or assessment of laboratory analysis or other monitoring information.
- Example copies of the Complaints Register and the Environmental Data Record follow.

COMPLAINTS REGISTER

Time and date	Method of communication	Complainant contact details	Weather conditions	Details of complaint	Action taken	Name of person responsible	Signature	Which regulatory agencies were notified?*

** Name of officer, agency and date*

ENVIRONMENTAL DATA RECORD

Date	Item	Comment/Action Taken	Effectiveness of action taken	Requirement/ recommendation for changes to procedures	Signature of officer responsible

Appendix 2.

Managing human exposure to contaminants

Feedlot wastes include a range of pathogens and may contain traces of hormonal growth promotants (HGPs), paraciticides and other chemicals used within the feedlot. This appendix outlines the main areas and activities where people may be exposed to these contaminants and describes practical ways to minimise risks.

CONTENTS

Risk assessment

An assessment of the risks that pathogens and chemicals in feedlot wastes pose to humans found that

- Pen manure is the waste of most concern.
- Fine particles in the air, particularly from pen manure, pose a relatively high risk.
- Pathogens pose most risk, although there are practical ways to reduce their numbers.
- The overall risk to people posed by hormones and paraciticides in manure is low to negligible, even under high exposure.

Contaminants in feedlot manure

The most abundant pathogens in manure from Australian feedlots are

- (EHEC/EPEC) *E. coli* group
- *Listeria monocytogenes*
- *Campylobacter jejuni*
- *Cryptosporidium parvum*
- *Giardia lamblia*.

Less abundant, but still sporadically detected, are

- *Salmonella enterica*
- *Yersinia pseudotuberculosis*
- *Leptospira* spp
- *Coxiella burnetii* (Q Fever)
- *Mycobacterium paratuberculosis*.

Chemicals are generally present in low concentrations, if at all.

General recommendations

– for staff

A number of practices will help to protect staff.

Management should

- have high quality (P2) face masks available for staff working under dusty conditions, and encourage staff to use these.
- avoid transporting or handling very dry manure. Consider wetting the manure beforehand, or moving or handling it when it is damp e.g. early morning or after light rain.
- provide machinery with an enclosed cab and recirculated air conditioning.
- fit offices with air filters.
- make staff aware that
  - fine pen dust poses the greatest risk
  - manure, particularly pen manure, contains pathogens that may cause illnesses
  - health risks can be minimised by adopting good hygiene practices. Staff should always wash their hands well after handling manure, compost, effluent or mortalities, especially before touching food, eating or drinking utensils, their eyes or other people.

Staff should avoid or minimise

- pen riding or other work in the pen area under dusty conditions e.g. windy days or later in the afternoon when there is increased cattle activity.
- working downwind of dusty activities for long periods without protection.
- disturbing, moving or transporting dry pen manure.
- interaction with dust on machinery, fences and roads.

– for feedlot visitors

Recommendations for on-farm visitors include

- discouraging people from visiting the feedlot if they have a medical condition that reduces their immunity, are pregnant or are accompanied by children.
- making visitors aware that:
  - feedlot wastes, particularly pen manure, contains pathogens that may cause illnesses
  - fine pen dust poses the greatest risk
  - health risks can be minimised by adopting the same good hygiene practices recommended for staff.

Reducing risk

– from manure handling

The following are recommendations for those handling manure

- Minimise dust generation and exposure during pen cleaning and initial handling of harvested manure. For instance, avoid pen areas during cleaning unless wearing a protective mask or staying within an enclosed cab.
- Avoid frequent exposure to dust plumes from aged manure and compost. Infrequent periodic exposure is less of a concern.

- Standardise manure processing methods to minimise risk and maximise pathothen destruction e.g. regularly measuring windrow temperatures and ensuring sufficient storage time before utilisation.
- Composting or other disinfection is strongly recommended before manure and effluent are utilised or sent off-site. Pathogens are inactivated by high manure temperatures so all material must be exposed to heat. Monitor windrows to ensure they heat up and maintain temperatures of >55°C for at least three consecutive days then turn. Repeat two more times. Higher temperatures will promote more rapid destruction. As a guide, composting manure for two months should minimise the most abundant pathogens. Windrow storage alone is insufficient.
- A windrow monitoring and recording system should include
  - recording of the date each windrow is started, turned, watered or amended
  - regular measurement of the core temperature at ten points within each windrow to ensure high temperatures are sustained for sufficient time (at least three consecutive days) after each windrow turn
  - details of the types and amounts of any amendments used.
- Pathogen destruction can be verified using E. coli and enterococci testing, e.g. Enterolert[tm] and Colilert[tm] to ensure numbers are <10 mpn/g (mpn = most probable number).

– from manure utilisation

Recommendations covering manure utilisation and transport include

- Do not spread manure during windy conditions.
- Avoid spreading very dry manure.
- Do not use spinning disc spreaders without dust management (e.g. sufficient moisture content in manure to minimise releases of fine aerosols).
- Before exporting manure, store for at least two to four months to reduce pathogen numbers.
- Compost manure using best management practices before sending off-site.
- Provide manure recipients with information about the pathogens that may be in manure and compost, and ways to avoid exposure.
- Ensure that recipients are aware of the need to provide appropriate warnings, disinfection /processing summaries and possibly microbiological quality control test data with commercially sold material.
- Cover loads of composted and aged manure if they are to be transported along public roads.
- Manure from grazing cattle would normally contain much higher pathogen loads than any composted or aged manure. Thus the use of manure for broadacre farming is reasonable.
- Do not spread manure when rain is expected or under overcast conditions.
- If manure or compost will be utilised in horticulture and organic farming, ensure pasteurisation is effective.

– from effluent utilisation

Recommendations pertaining to effluent irrigation include

- Make staff aware that effluent is likely to have a high pathogen content.
- If possible, store the effluent for at least a month before irrigation.
- Effluent should be irrigated only when the soil is dry and no immediate rain is forecast.
- Low-pressure spray irrigation is recommended.
- Avoid high-pressure irrigation systems that generate aerosols.
- Avoid working downwind of spray irrigators.
- Avoid irrigating on windy days.
- Flood irrigation reduces aerosols. Well-designed flood systems are recommended where suitable.
- Keep vegetated buffers between utilisation areas and watercourses and farm boundaries.
- Irrigate the effluent evenly and at environmentally sustainable nutrient rates.

– to livestock accessing utilisation areas

To reduce the pathogen risks to livestock grazing utilisation areas

- Apply a withholding period of 21 days after spreading manure or effluent, including tailwater and stormwater runoff from utilisation areas.
- Do not irrigate effluent onto a hay or silage crop during the week before harvest.
- Do not spread carcase compost onto areas being grazed by livestock.

Further reading

DAFF 2011, Using weather conditions to reduce odour impacts, Department of Agriculture, Fisheries and Forestry, Brisbane, Qld.

Roser D, Tucker R, Khan S, Klein M, Coleman H, Brown L, et al. 2011, Microbiological and chemical human health risks arising from cattle feedlot wastes: Their characterisation and management, Report for MLA Project FLOT.333: Managing the Contaminants in Feedlot Wastes, Meat & Livestock Australia, North Sydney, NSW.

Wilkinson KG. 2007, 'The biosecurity of on-farm mortality composting', Journal of Applied Microbiology,102:609–618.

Appendix 3.
Duty of care: waste utilisation

Introduction

Aged manure, compost and liquid effluent from beef feedlots are good sources of nutrients for plant growth and organic matter for building soil structure. However, like inorganic fertilisers, these wastes need to be spread on suitable areas and applied at sustainable rates to ensure the environment is protected and maximum benefit obtained.

Those utilising feedlot wastes must take reasonable and practical steps to prevent harm to the environment.

Potential impacts

In particular, spreading of feedlot wastes needs to be managed to avoid

- land degradation (e.g. soil erosion, decline in soil structure, nutrient overloading)
- odour and dust nuisance
- surface water and groundwater pollution with nutrients and sediment
- increased weeds
- noise nuisance.

Minimising impacts

To minimise the likelihood of impacts

- Prevent manure or compost spillage during transportation by not overfilling trucks and by covering loads.
- Avoid transport routes with many houses or public use areas close to the road.
- Do not spread manure, compost or liquid effluent on areas that are flood-prone or where there is a significant risk of nutrient transfer to watercourses (e.g. sloping land immediately abutting a watercourse).
- Advise neighbours of the proposed activity and ensure there are no social events planned
- Before spreading waste, check the weather forecast and delay spreading if rain is expected or the soil is still very wet following rain. Check the wind speed and direction to ensure the prevailing wind is not blowing directly towards nearby residences.
- Plan to spread waste from mid-morning to early-afternoon when good odour dispersion is likely. Avoid spreading from mid-afternoon to evening and also just before weekends or public holidays, particularly if close to a public area.
- Determine a suitable spreading rate based on the N, P and K content of the waste, soil properties and the intended land use of the utilisation area. The rate should be consistent with the ability of soils and plants grown on the area to sustainably use the applied nutrients, salts and carbon in the manure, compost or liquid effluent.
- Advise staff to take appropriate precautions to protect against risks, including using personal protection equipment. This may include high-quality (P2) dust masks, overalls and disposable gloves.
- Calibrate the manure spreader/irrigator to spread at the target rate.
- Incorporate waste into the soil as soon as practical to minimise nitrogen loss, GHG emissions and odour.
- Although the manure aging and composting processes can destroy most weed seeds, some seeds may remain viable. Monitor the utilisation area and control weeds if necessary.
- Avoid spreading waste close to sensitive neighbours at night when noise may create nuisance.

NOTE: A recent ‘typical analysis’ sheet for the waste should also be provided to the recipient.

Appendix 4.
Manure valuation pro forma

Introduction

The nutrients in aged feedlot manure and compost have significant value in cropping or pasture systems and need to be valued appropriately. This appendix provides a method using fertiliser price and manure nutrient content to place a value on manure.

Quantify the nutrient content of the aged manure or compost

Table A4.1 shows the typical composition of aged beef feedlot manure and compost.

Table A4.1 Typical composition of aged beef feedlot manure and compost

Parameter	Aged manure	Compost
Dry matter (%)	63.2	74.0
Volatile solids (% db)	67.5	43.7
Total nitrogen (% db)	2.18	2.11
Total phosphorus (% db)	0.80	1.31
Potassium (% db)	1.86	2.49
Sodium (% db)	0.30	0.43
Sulfur (% db)	0.45	0.52
Calcium (% db)	2.22	1.91
Magnesium (% db)	0.86	0.93
EC1:5 (dS/m)	8.3	16.1
pH	7.2	7.3
Ammonia-N (mg/kg db)	1,431	1,016
Nitrate-N (mg/kg db)	307	714
Boron (mg/kg db)	22	23
Cobalt (mg/kg db)	7	-
Copper (mg/kg db)	35	37
Iron (mg/kg db)	11,700	5,300
Manganese (mg/kg db)	387	351
Molybdenum (mg/kg db)	4.3	5.7
Ortho-phosphate (mg/kg db)	944	3,100
Zinc (mg/kg db)	221	254

A significant proportion of the nitrogen in aged manure and compost is lost to the atmosphere through release as ammonia following spreading, especially if the manure is not incorporated into the soil. If nitrogen losses are expected to be 40% for aged manure and 25% for compost, the net amount of nitrogen remaining after spreading would be 1.31% and 1.58% respectively.

Value the nutrients in inorganic fertilisers

It is possible to value the nitrogen (N), phosphorus (P) and potassium (K) in aged manure or compost using the value of these nutrients in inorganic fertilisers. Table A4.2 shows the typical composition of a range of common fertiliser products. Commercial, bulk-delivered fertiliser prices (ex GST) were obtained for common nitrogen, phosphorus and potassium fertilisers (see Table A4.3). These were \$550/t for urea, \$800/t for DAP and \$800/t for muriate of potash (Nov 2012). These were used to calculate values for N, P and K.

Table A4.2 Typical composition of common N, P and K fertilisers

Fertiliser	Macro-nutrient content (%)		
	N	P	K
Anhydrous ammonia	82.3	-	-
Urea	46	-	-
UAN (urea-ammonium nitrate)	42	-	-
MAP	10	22.6	-
DAP	17.5	20.0	-
Superphosphate	-	9.1	-
Double superphosphate	-	17.5	-
Triple superphosphate	-	20	-
Ammonium sulfate	21	-	-
Muriate of potash	-	-	50
Potassium sulfate	-	-	41
Potassium magnesium sulfate	-	-	18
Potassium nitrate	13	-	38

Table A4.3 Value of macronutrients in inorganic fertilisers (November 2014)

Fertiliser	Total delivered price (ex GST) $/tonne	Value of target nutrient $/tonne	Target nutrient content (%)	Nutrient value ($/kg)
Urea (value of N)	$550	$550	46% N	N = $1.20/kg
DAP (value of P)	$800	$590	20% P	P = $2.95/kg
Muriate of potash (value of K)	$800	$800	50% K	K = $1.60/kg

Since urea is 46% nitrogen and costs $550/t, nitrogen can be valued at $1.20/kg (i.e. ($550/0.46)/1,000). Where a fertiliser product contains multiple nutrients their value should be separated out. For instance, DAP contains 17.5% nitrogen and 20% phosphorus and costs $800/t. For the purpose of this exercise we are interested in the value of the phosphorus. The nitrogen in DAP is worth about $210/t (i.e. 175 kg/t@$1.20) Subtracting this from the total fertiliser cost gives a phosphorus value of about $590/t or $2.95/kg. The potassium in muriate of potash is worth $1.60/kg (i.e. ($800/0.5)/1,000). Thus in this case, nitrogen is valued at $1.20/kg, phosphorus at $2.95/kg and potassium at $1.60/kg (see Table A4.3).

Applying the fertiliser nutrient values to the nutrients in aged manure or compost

The gross nutrient values ($/kg) for N, P and K calculated in the previous step can be applied to nutrients in the manure or compost to obtain a macronutrient value for the product. Table A4.4 and Table A4.5 provide a summary for aged manure and compost respectively.

The composition of aged feedlot manure and compost can vary widely. To achieve greater accuracy, use site-specific data for the composition of aged manure or compost and up to date fertiliser prices.

Care must be taken when comparing the values in these tables with costs for inorganic fertilisers. Remember that

- Nutrients are only of value if they are needed in the cropping system. For example, if the soil is deficient in N but has adequate P and K, the latter provide no additional value. Hence, the N value is also the manure value. However if multiple nutrients are needed, the value of these can be summed up to estimate the real value of the manure or compost to the recipient.
- N losses after spreading must be considered. If the manure is not incorporated into the soil immediately, losses could be significant with a corresponding reduction in the N value of the manure. The aged manure and compost N values in Tables A4.4 and A4.5 take into account suggested ammonia losses.
- The rates of availability of nutrients vary in manure and compost. For example, only one third of the N in the manure may be available in year one and depending on release rate in that year, 20–30% could be available in year two.
- P availability also varies widely. Where soils are P deficient, about 70% of the P in the manure is probably available in the first year, but this could be much lower.
  The value of the manure or compost nutrients should be spread over 2–3 years as they become available to plants. The value of the nutrient contribution in any given year can be calculated by multiplying the percentage of the nutrient expected to be available in that year by the monetary contribution for that nutrient.
- Aged beef feedlot manure and compost do not supply nutrients in the ideal ratios for plant needs. They are often best used in conjunction with an inorganic fertiliser program designed to meet plant requirements.
  One option is to apply the manure or compost at a rate that meets P requirements and then supplement the N to meet crop needs. An alternative is to apply the manure or compost at a rate that meets crop N requirements if the soil is able to store the surplus P. If this option is chosen, N availability in the first year needs to be considered.
  Storage of P in the soil should be regarded as a temporary measure. The P concentration should be reduced to a sustainable level before additional manure or compost is applied.

- The valuation above does not consider the contribution of other elements such as sulfur, zinc, calcium, magnesium, boron, copper and other trace elements that may be valuable to the cropping system depending on the soil nutrient status. If these are deficient, their value can be added to the macronutrient value. For example, sulfur and zinc are likely to be deficient on the black cracking clays of the Darling Downs and the value of these two nutrients could add $3-6/t to the value of feedlot manure.

Manure and compost also add carbon as organic matter to the soil. This helps to improve the soil's structure and water-holding capacity and reduce its erosivity. It is difficult to put a dollar value on these benefits.

Table A4.4 Value of nutrients in aged feedlot manure

Parameter	Manure analysis (% dry basis)	Manure analysis (as spread)	Mass of nutrient per wet tonne (kg/t)	Value from inorganic fertiliser rate ($/kg)
Dry matter	63	–	–	–
Total nitrogen	2.18	1.37	13.7	–
Nitrogen (after ammonia losses)	1.31	0.84	8.4	$10.08
Phosphorus	0.80	0.50	5.0	$14.75
Potassium	1.86	1.17	11.7	$18.72

Table A4.5 Value of nutrients in feedlot compost

Parameter	Compost analysis (% dry basis)	Compost analysis (as spread)	Mass of nutrient per wet tonne (kg/t)	Value from inorganic fertiliser rate ($/kg)
Dry matter	74	–	–	–
Total nitrogen	2.11	1.58	15.8	–
Nitrogen (after ammonia losses)	1.58	1.11	11.1	$13.32
Phosphorus	1.31	0.96	9.6	$28.32
Potassium	2.49	1.84	18.4	$29.44

Example

Is it more cost effective to spread aged manure or spread DAP on paddocks with soils that are deficient in nitrogen and phosphorus but have adequate potassium?

Details:

- planned application rate 4 t/ha
- cost of aged manure (ex-feedlot) $8/t
- cost of cartage and spreading $15/t
- DAP costs $800/t delivered and could be spread in conjunction with other activities (i.e. at no extra cost) at seeding time.

On a dry matter basis, the aged manure contains 2.18% nitrogen (1.31% after accounting for ammonia losses) and 0.80% phosphorus. With a moisture content of 37%, the manure as spread contains 0.83% nitrogen (after accounting for gaseous losses) (i.e. 1.31 × 0.63) and 0.50% phosphorus (i.e. 0.80% × 0.63).

Based on the cost and nutrient content of inorganic fertilisers, N in the manure is valued at $1.20/kg, P at $2.95 and K at $1.60, but extra K has no value on this soil.

Details of the nutrient content of the manure, the application rate, the nutrients applied and the value of these are tabulated below.

Nutrient	Nutrient content (% as spread)	Nutrients applied (kg/t)	Nutrients applied @ 4 t/ha (kg/ha)	Value of nutrients applied ($/ha)
N (after gaseous losses)	0.83	8.3	33.2	$40
P	0.50	5.0	20.0	$59
Total value				$99

The cost to purchase, cart and spread this manure at 4 t/ha must be compared with the cost for applying the DAP.

An analysis of the net value of nutrients in the manure, after accounting for all costs, is tabulated below.

Item	Cost ($/t)	Cost ($@4 t/ha)
Manure	8	$32
Freight and spreading	15	$60
Total cost	23	$92
Nutrient value (based on cost of inorganic fertiliser)		$99
Economic advantage of aged feedlot manure		$7

In this example, there is an economic advantage of $7/ha to using aged feedlot manure rather than DAP and urea.

Any economic advantage to using feedlot manure is strongly influenced by the cost of cartage and spreading (which includes cartage distances and contractors rates) and the current cost of artifical fertilisers.

Use site-specific data for the composition of aged manure or compost, up to date fertiliser prices and relevant cartage distances and spreading costs.

Appendix 5.

Advances in waste treatment

Increasing environmental pressures and economic incentives to reduce greenhouse gas (GHG) emissions are raising interest in waste-to-energy projects.

CONTENTS

Introduction

Increasing environmental pressures and economic incentives for industries and enterprises to reduce greenhouse gas (GHG) emissions have boosted interest in waste-to-energy projects.

The success of these types of projects in other industries such as intensive pig farming, and economic drivers to save money through power creation, possible trading of carbon credits and the potential to produce more 'fertiliser-type' products from manure, are driving interest in advanced waste treatment strategies.

Fresh beef feedlot manure has a relatively high energy content and offers the potential for energy recovery. However, factors that can reduce the energy potential of feedlot manure include the breakdown on the feedlot pad, high moisture content and contamination by soil and gravel. To date there is no full-scale example in Australia of energy recovery from feedlot manure and only limited data is available from overseas.

Advanced treatment of manure

A range of advanced technologies could be used to generate power and extract nutrients from beef cattle manure. These technologies usually fall into one of three categories

- anaerobic digestion
- thermal treatment
- diet modifications.

Of the three categories, anaerobic digestion has shown the most potential to date for extensive use in Australian livestock manure management for both capture and reuse of methane and for flaring unwanted biogas.

Dietary modification and thermal treatments could be used with anaerobic digestion as part of an overall GHG mitigation strategy.

Thermal treatments are energy intensive and require significant investment in engineering technology; there have been some successes but also large-scale failures.

Thermal treatments such as gasification, pyrolysis and direct combustion have been used in the US and Europe but have had only limited application in Australia. An Australian desktop study identified that energy recovery from harvested manure using thermal techniques appeared to offer attractive economics even for medium-sized feedlots of 10,000 SCU (Bridle 2011), but the study was based on using freshly harvested manure which may not be practical for commercial feedlots.

Anaerobic digestion of beef feedlot manure

Anaerobic digestion is one of the more promising waste-to-energy techniques. The biogas generated is readily used as an energy source while digestate from this process is often rich in ammonium and phosphate that can be recovered via crystallisation, potentially for conversion into marketable fertilisers (Gaterell et al. 2000). Anaerobic digestion also has other advantages such as the destruction of pathogenic and parasitic organisms, low biomass production, good process stability and relatively low treatment cost (Quan et al. 2010).

Basically, anaerobic digestion involves mixing manure with water and storing it in a closed space; microbial digestion of organic matter in the absence of oxygen produces biogas consisting mostly of methane and carbon dioxide.

Anaerobic digestion systems include

- High-rate anaerobic digesters – these normally operate with short hydraulic retention times (typically <48 hours) but can extend solids retention times by integrating solids retention within the main digester. The most common type is an upflow anaerobic sludge blanket (UASB) reactor. These require a low solids feed with relatively high levels of soluble material. They are most often used for domestic sewage treatment and industrial wastewaters (van Lier 2008)
- Covered anaerobic ponds – a heavily loaded pond is covered and the biogas collected from under the cover. This has a low capital cost but relatively large footprint. Regular pond desludging is needed which can be difficult and costly. Because of the large volumes, failure correction can be expensive or impractical
- Liquid mixed digesters – these operate as a fully mixed system with either gas recirculation or mechanical mixing. The maximum in-reactor solids concentration is around 6%
- Liquid plug flow – in this system, semi-solid liquids (10–20% dry matter) pass through a long polyethylene tube or concrete facility. As these systems are not mixed, contact with biomass is poor

- Solid phase (leach bed) – material is loaded into a reactor with leachate liquid circulated through it. Leach beds can operate as either batch or continuous systems with the latter being considerably more expensive (Pavlostathis and Giraldo-Gomez 1991).

Anaerobic digestion of feedlot manure on a commercial scale is yet to be implemented in Australia. Various anaerobic digestion technologies including liquid mixed digesters, covered anaerobic ponds, liquid plug flow and mixed plug flow digestion have been applied to cattle manure in North America (Pillars 2003).

There are significant issues with anaerobic digestion of feedlot manure. In particular, the biological methane potential of harvested manure is relatively low due to its rapid deterioration on the feedlot pad. Optimising the solids concentration for conventional digestion would also require a significant volume of water during the drier months. Nevertheless, a conventional anaerobic digestion system could operate economically in Australian beef feedlots if water were available. The disposal of the resultant saline effluent is an issue (Hertle 2008).

Combustion

Direct combustion is the simplest method of converting waste to energy. It involves burning material in the presence of oxygen to produce heat energy. This heat can then create other forms of energy including steam, hot water or hot air. Direct combustion is also one of the most commonly used technologies, particularly in developing countries where dry cattle dung is used as fuel for domestic cooking.

Typical combustion temperatures for biomass from a livestock origin are 300–550°C. In most direct combustion operations heat energy is used to turn water into steam. Steam may be used to create electricity or a transportable form of heat (Baranyai and Bradley 2008). Waste-to-energy systems that generate both electricity and a source of heat are called cogeneration facilities. The most common method of producing steam is the direct combustion of a fuel beneath boilers.

The moisture content of the biomass being burnt is a major determinant of the efficiency of combustion systems. As the initial phase of combustion involves water evaporation, a lower moisture content means less heat is required to achieve combustion. The suggested optimal moisture content is between 15 and 20%. Wet materials also cause large variations in temperature, leading to inefficient energy conversion, incomplete combustion and the potential build-up of combustible gases (Antares Group Incorporated et al. 1999).

Combustion is a relatively inefficient method of converting biomass into energy, with small combustion systems having heat losses of 30–90% of the original energy potential. Unlike the digestion process not all the nutrients are retained during combustion. Although more than 90% of both phosphorus and potassium remain in the ash after combustion at both 300°C and 550°C, about 44% of the nitrogen is lost at 300°C and 94% at 550°C (Roberts et al. 2009).

Despite promising initial desktop studies, preliminary Australian trials of combustion of harvested beef feedlot manure were unable to demonstrate that this was viable. Further research is required before it is dismissed altogether (Watts et al. 2012).

Pyrolysis

Pyrolysis is the chemical decomposition of a material by heat in the absence of oxygen or oxidising agents. Pyrolysis converts the organic portion of the biomass into a mixture of char and volatile gases containing non-condensable vapours and condensable tars (oxygenated hydrocarbons) which form a pyrolytic oil or bio-oil (Bridgewater 2003). Gases including methane, ethane and acetylene are produced by the process along with ash.

Pyrolysis can be divided broadly into slow or fast pyrolysis, or by the operating temperature. Low temperature slow pyrolysis produces more biochar (and less energy) and is commonly promoted for biochar production. High temperature (approximately 500°C), fast pyrolysis produces more liquid and gas from the same product and less biochar.

Pyrolysis conditions such as temperature and feedstock properties of particle size, lignin and inorganic matter content are key factors influencing the quality of the biochar produced (Demirbas 2004).

Bio-oil has been successfully fired in several diesel test engines where it behaves similarly to diesel in terms of engine parameters, performance and emissions. Work in this area is still in its infancy but there is a considerable effort currently occurring to improve the technology.

Gasification

Gasification is the process of converting materials into a hydrocarbon gas (syngas) through the application of very high temperatures in the absence of oxygen. Syngas consists of carbon monoxide, hydrogen, carbon dioxide and methane. It can be burnt to produce steam or electricity and has the potential to be used in normal combustion engines. Compared to direct combustion, gasification produces carbon and hydrogen-rich fuels which provide more flexibility for energy generation, often with improved efficiencies and environmental performance.

Gasifiers can be categorised into four separate systems

- *Downdraft* – the most common system. Biomass enters the system at the top of the unit and proceeds downwards. Air is fed into the unit above the point where syngas exits (Lynch 2006)
- *Updraft* – the simplest system to operate. Biomass is added to the top of the unit and air is added at the base. The updraft causes ash to settle downwards while the syngas exits near the top. This system has greater tar and failure problems (FAO 1986)
- *Crossdraft* – this type of system pushes air flow across the chamber. Biomass is still added at the top of the unit but the reactions occur sequentially between the air inlet and gas outlet. The proximity of the inlet and outlet increases tar collection problems and requires high quality material to be used. This type of system can be highly economical (FAO 1986)
- *Fluidised bed* – the most complex of the four systems, but it can manage a much wider range of biomass materials. Air is blown through a uniform, heated bedding material causing the material to remain in a suspended state. Biomass added to the bedding material reaches pyrolysis temperature quickly, significantly increasing the amount of syngas generated.

Conventional gasifiers are not compatible with the high silica and ash content in feedlot manure so specialised equipment would need to be developed (Madden 2011).

A major advantage of gasification over direct combustion is lower GHG emissions (including nitrous oxide) with some nitrogen retained and the remainder lost as ammonia. The retention of nitrogen increases the nutrient value and potential price of the resultant by-products. However, gasification is an expensive technology to design, construct, operate and maintain. Gasification facilities require considerable preparation and drying of biomass fuels and substantial heat inputs. Studies have indicated that biomass gasification facilities, especially ethanol production facilities, benefit from economies of scale and need to be large to be viable (Yakima County Public Works 2003).

There has been limited research involving gasification of feedlot manure. For example in Texas, feedlot manure and chicken litter were used as inputs to a fixed bed gasification system (Priyadarsan et al. 2004). The feedlot manure was a blend of 70% manure from a soil-surfaced feedlot and 30% manure from a fly-ash bedded feedlot. The resulting manure had an ash content of around 45% by weight. Three different fuels were tested: the feedlot manure blend, chicken litter and a 50:50 blend of feedlot manure and chicken litter. Both the feedlot manure and the chicken litter could be gasified to produce low-BTU gas with a heating range of 4-4.8 MJ/m^3. However, the high-alkaline chicken litter resulted in agglomeration in the bed which reduced the bed's peak temperature and peak-temperature propagation rate. Blending it with feedlot manure addressed this issue without significantly reducing the heating value of the gas produced.

In Australia, gasification trials using beef feedlot manure have so far been unable to demonstrate that harvested pen manure is suitable for conversion into syngas (Watts et al. 2012). Further research is warranted.

The future

Renewable energy technologies can be cost-competitive in providing energy and industrial heat for Australian agribusinesses but the scale and mix of technologies will be different for each business (Edgerton 2012).

Covered anaerobic ponds or purpose-built anaerobic digesters could possibly be viable systems for beef feedlot manure but there are significant issues to address, including ensuring a regular supply stream of relatively fresh manure. Covering feedlot holding ponds to capture biogas for use as an energy source is not economically attractive, even for large feedlots (Bridle Consulting 2011).

To date, Australian farm-scale trials have been unable to demonstrate that combustion and gasification technologies can be feasibly used to process beef feedlot manure (Watts et al. 2012).

Advanced treatment of effluent

In response to changes in water availability and cost of supply, the industry has expressed interest in treating and reusing effluent as part of the water supply for feedlots.

The major water use within feedlots is drinking water for cattle but significant amounts can be used to wash the animals. In most locations the long-term sustainable effluent yield is around 2.5–5 ML/1000 head/year (Tucker et al. 2011b). Reuse of treated effluent within the feedlot could meet 20–30% of the total drinking water requirement.

Feedlot effluent is a reasonably concentrated wastewater with considerable colour and high concentrations of both inorganic and organic nutrients. Microbiological contamination is a key parameter pertaining to the treatment requirements and safe reuse of effluent, since the pathogen load in raw effluent can be quite high.

Effluent would need extensive tertiary treatment to allow for safe consumption by cattle. Treatments would need to dilute or partially remove salt and considerably reduce organic matter, colour and nutrients to ensure effluent stability and efficient disinfection. At present, the high cost of treating water to this standard would put those installing such a plant at a commercial disadvantage compared to feedlots that have access to cheaper water (Tucker et al. 2011b).

As the recent public debates about recycled water have shown there are other factors to be considered, regardless of whether the risks associated with recycled water are perceived or real. Water recycling in the beef industry is unlikely to be an option for most of the industry unless water prices increase considerably.

Further reading

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Appendix 6.
NFAS Manual sample elements

Element LM 6 – Biosecurity

Who:	Feedlot manager
Where:	Feedlot
When:	At all times

Actions

To minimise the likelihood of a disease entering and spreading within the feedlot, the following actions are undertaken.

Staff training

1. Ensure all feedlot staff are aware of the potential for the introduction of diseases including emergency diseases as defined in the AUSVETPLAN.
2. Ensure all staff are familiar with and understand the mechanisms of the spread of disease including the potential introduction and spread of the disease by
   - livestock and feed commodities
   - visitors and employees
   - vehicles, equipment and machinery
   - feral animals and wildlife
   - manure and effluent.
3. All staff involved in the daily monitoring of livestock health are trained in the early detection of livestock diseases and are aware of their responsibilities under the Emergency Animal Disease Action Plan.

Access control

1. Movements of incoming and outgoing vehicles, machinery and equipment are controlled by marked roadways and signage.
2. All visitors to the feedlot must report to the office where their biosecurity risk is assessed and recorded prior to accessing the feedlot site.
3. High biosecurity risk visitors are not permitted access to animal or commodity/feed areas.
4. Moderate biosecurity risk visitors are only permitted access to animal and commodity/feed areas with the use of protective clothing.

Element LM 6 – Biosecurity (continued)

Access control (continued)

5. Visitors log must be maintained that includes the following information
   - Date
   - Time in
   - Name
   - Time out
   - Company
   - Contact number
   - Signature
   - Biosecurity risk assessment

Animal health

1. All animals are inspected on intake for illness and physical injuries and records maintained of the inspection.
2. Cattle are checked and observed daily for health and wellbeing and records of the inspection maintained.
3. Where a potential emergency disease outbreak is suspected, requirements of the Emergency Animal Disease (EAD) Action Plan are implemented as detailed in the contingency planning procedure.

Equipment and machinery

1. No machinery or equipment is to be routinely used for multiple activities such as handling stockfeed, manure or dead stock. Where required, all equipment and machinery shall be thoroughly washed down to remove all potential sources of cross contamination.

Dead stock management

1. Dead stock are disposed of in the manure stockpile which is located within the controlled drainage area. Disposal of dead stock is conducted as soon as possible to minimise odour generation.
2. Mortalities are only handled with equipment that is not used in feed processing.
3. Prior to burial, details of the dead animal are recorded including
   - Date
   - Lot number/owner
   - Individual number
   - Cause of death
   - All tags are removed (NLIS, management and feedlot).
4. A necropsy is conducted on all animals that have died at the feedlot. Consultation with the local vet is sought if there are any unfamiliar or suspicious signs surrounding the death.
5. The animal is placed in the manure stockpile and covered with a minimum of 0.6m of hay/sawdust and manure to aid in the decomposition of the animal and prevent odour generation and fly/vermin breeding. When an animal is placed in the manure stockpile, the location is marked for future reference.

Element LM 6 – Biosecurity (continued)

Dead stock management (continued)

6. The carcase is kept covered at all times and is left in the stockpile for 12 months. This allows for the total active composting plus curing.
7. In the event of mass mortalities at the feedlot, a burial pit would be constructed in accordance with the AUSVETPLAN Enterprise Manual – Feedlots.

Manure and effluent management

1. Pens are cleaned regularly at intervals of 13 weeks or less.
2. Pens are best cleaned when the manure is moist but not wet. However, they have to be cleaned regularly regardless of the manure moisture content. Pens are cleaned to maintain a maximum compacted manure depth of 100 mm over the pad.
3. Manure is first removed from under fence lines, around water troughs, shade posts and along and behind the aprons using a bobcat, under-fence pusher, slider blade or other equipment. Very wet manure is not harvested.
4. Manure is then scraped from the pen surface into a mound. If an interface layer is to be retained, great care is taken with depth control.
5. Pen cleaning activities are noted in the Environmental Data Record.
6. Generally the manure will be removed promptly either to the manure stockpiling/composting area or off-site.
7. Harvested manure can be stored prior to sale or spreading on designated areas.
8. Manure is only spread on the land areas specified on the state feedlot licence and in compliance with the requirements noted on the state feedlot licence.
9. Spread manure is incorporated where possible so that the impact on neighbours is minimal.
10. Effluent is only spread on the land areas specified on the state feedlot licence and in compliance with the requirements noted on the state feedlot licence.
11. Manure and effluent spreading activities are detailed in the Environmental Data Record.
12. Drains, the sedimentation trap and the ponds are cleaned and maintained as required.
13. Cleaning and maintenance activities are noted in the Environmental Data Record.

Spoilt feed management

1. All care is taken to minimise feed spillage during feed delivery.
2. Feed residues are removed from feed bunks on a daily basis to minimise odour generation and/or vermin breeding.
3. Spoilt or wet feed is removed from the bunks using a shovel or brush.
4. The material is either thrown into the pen area for removal during pen cleaning operations or is taken straight to the manure stockpiling/composting area.
5. Spoilt feed deposited in the manure stockpile area is subsequently mixed with the manure stored in stockpiles.

Element LM 6 – Biosecurity (continued)

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Emergency Animal Disease (EAD) Action Plan

AUSVETPLAN

Beef cattle feedlots: Waste management and utilisation

Feedlot site layout

Feedlot visitor log

Biosecurity Risk Assessment

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Cattle Arrival Reports

Cattle Inspection Records

Cattle Treatment Records

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Glossary

Aerobic: An environment in which oxygen is present, either in a gaseous or a dissolved form (see *Anaerobic* and *Facultative*).

Amenity: The maintenance of the environmental attributes that contribute to physical or material comfort of community members.

Anaerobic: An environment in which oxygen is absent or unavailable. In feedlots anaerobic conditions commonly occur in holding ponds and manure on the pen surface or in static manure stockpiles.

Anaerobic pond: A wastewater holding pond in which anaerobic conditions prevail. Anaerobic conditions in feedlot holding ponds typically arise where microbial degradation of organic constituents consumes the available oxygen at a rate faster that it can dissolve from the atmosphere into the wastewater.

Ash: see *Fixed solids*.

Beef cattle feedlot: A beef cattle feedlot is a confined yard area with watering and feeding facilities where cattle are completely fed by hand or mechanically for the purpose of beef production. This definition includes covered and uncovered yards.

This definition does not include the feeding or penning of cattle in the following situations

- for weaning, dipping or similar husbandry practices
- for milk production
- at a depot operated exclusively for the assembly of cattle for live export
- for drought or emergency feeding purposes
- at a slaughtering facility
- in recognised saleyards.

Buffer: The distance between a feedlot complex or waste utilisation area and a watercourse or wetland when considering waste material such as manure or effluent.

Compost: An organic material that has undergone aerobic and thermophilic treatment and has achieved a suitable level of 'pasteurisation' and stabilisation or 'maturity'.

Contamination: see *Pollution*

Controlled drainage area (CDA): A controlled drainage area is a self-contained catchment surrounding those parts of the feedlot complex from which uncontrolled stormwater runoff would constitute an environmental hazard. It is typically established using a series of catch drains to capture runoff from the feedlot pens and all other surfaces within the feedlot complex, and ultimately convey that runoff to a collection or disposal system. Diversion banks or drains are placed immediately upslope of the feedlot complex, which are designed to divert 'clean' or uncontaminated upslope runoff around the feedlot complex.
Note: Where feedlots are built close to the crest of a hill or ridge and there will be no runoff from upslope, it is possible to have a controlled drainage area without any diversion banks or drains.

Drain or catch drain: A gutter or channel that captures runoff from within the controlled drainage area and conveys it to the sedimentation system and ultimately to the holding pond.

Dry basis (db): Reporting of constituents in a material as a concentration in the dry matter (DM) component of that material.

Dry matter (DM): The matter remaining in a sample after all the water has been removed by oven drying, usually at a temperature of 105°C, until a stable weight is reached. It includes volatile solids (VS) and fixed solids (FS) or ash.

Effluent: The runoff from the feedlot controlled drainage area stored in the holding pond.

Effluent utilisation area: An area of land to which effluent is applied.

Electrical conductivity (EC): see *Salinity measurements*

Energy efficiency: The relationship between the energy input of a system and the output of that system.

Environment: The external or internal conditions (physical, chemical, biological, aesthetic or cultural) that influence the life and wellbeing of an individual plant or animal and its interrelationship with other organisms.

Feedlot: see *Beef cattle feedlot*

Feedlot complex: The feedlot complex includes

- pens
- handling yards
- drains, sedimentation systems and ponds

- stock lanes and feed alleys
- manure stockpile and composting pads
- feed mill and feed storage facilities (this may be separate to the feedlot facility)
- stock and vehicle washdown facilities.

The feedlot complex does not include manure and effluent utilisation areas.

Fixed solids (FS): The matter remaining after a dry matter (DM) sample has been burned at 440°C (ASTM) or 550°C (ALPHA 1989) or 750°C (ASTM) to remove volatile solids (VS).

Flooding: The inundation of land as the result of the overflow of a watercourse. Overland flow not directly associated with the overflow of a watercourse is not considered as flooding in this document. Alternative definitions may apply in local, state or federal government legislation and regulation.

Greenhouse gases (GHG): Certain gases such as methane and carbon dioxide which are implicated in the greenhouse effect.

Groundwater: Water beneath the surface of the land that is free to move under the effects of gravity.

Holding pond: A pond designed to capture and store the normal runoff or effluent before it is either applied to cropland or evaporated.

Interface layer: A compacted mixture of manure and soil that forms a moist, plastic, low-permeability layer between the feedlot pad and the overlying manure.

Leachate: A liquid containing soluble material removed from a solid mixture through which the liquid has passed.

Manure: The solid waste produced by cattle. In feedlots, this is the material that collects on the surface of the pen and consists principally of cattle dung and urine.

Manure utilisation area: An area of land to which manure is applied.

MEDLI: Model for Effluent Disposal by Land Irrigation.

Permeability: Permeability is the ability of a material to allow a fluid to flow through it. An impermeable material will not permit any fluid to pass through it. Note: Few materials are totally impermeable and as a result the term is frequently applied to materials that have very low permeability rather than being totally impermeable.

Pollution: The release of a pollutant into the environment such that the resultant effects become harmful to human health, other living organisms, or to the general environment. A pollutant may be chemical, physical, biological or energy (in the form of noise, heat or light). A resource is polluted if its environmental value is adversely altered.

Risk: Exposure to hazard (e.g. chance of injury or loss).

Runoff: Runoff consists of all surface water flow, both over the ground surface as overland flow and in streams as channel flow. It may originate from excess precipitation that cannot infiltrate the soil or as the outflow of groundwater along lines where the water table intersects the earth's surface.

Salinity: The level of soluble salts present in water or soil.

Salinity measurements: The electrical conductivity (EC) of water or a soil and water mixture is a widely accepted measure of *salinity*. Electrical conductivity is the ability of a solution to conduct electricity, which is directly proportional to the concentration and the ionic species present. In soil the electrical conductivity is usually measured in a mixture of one part soil to five parts water (i.e. $EC_{1:5}$). The significance of an $EC_{1:5}$ value in respect to plant toxicity is dependent on soil texture. As a result, laboratory $EC_{1:5}$ values are often mathematically converted to saturated extract electrical conductivity values. The resultant values are commonly referred to as EC_{se} or EC_e values. EC values obtained from electromagnetic induction surveys are termed apparent conductivity (EC_a). These values do not directly relate to laboratory measured electrical conductivity results.

Sedimentation basins: Type of sedimentation system that is wider, shorter and deeper than terraces but still a relatively shallow, free-draining structure. The maximum depth at the design flow rate should be one metre or less. Settled solids should be deposited as a relatively thin layer. Drying should be rapid enough to allow settled material to be removed within days (rather than weeks or months) of a major inflow event.

Sedimentation system: System to remove the readily settleable fraction of the solids entrained in effluent. A sedimentation system may be a pond, basin or terrace that discharges effluent to a holding pond.

Sedimentation tanks: Are designed not to be free-draining. They are usually deeper, shorter and wider than basins, and are intended to store settled solids for lengthy periods (e.g. 3–5 years) before cleaning. To accommodate such infrequent cleaning tanks are normally substantially deeper than one metre. Tanks may not dry out between rainfall events and thus may generate more odour than basins or terraces. The use of sedimentation tanks should be restricted to feedlots remote from sensitive receptors.

Sedimentation terraces: A type of sedimentation system that consists of long, shallow, free-draining structures. They are often used in small feedlots located on gently sloping terrain or in series in larger feedlots located on very flat sites, where the limited slope precludes the construction of 'normal' sedimentation basins. After a rainfall event sediment is deposited in a relatively thin layer which dries rapidly and can be removed soon after any inflow.

Separation distance: The separation distance is the distance between a likely source of an emission and a receptor likely to be sensitive to that emission. A separation distance (also variously referred to as buffer, setback or offset distance) is measured from the nearest physical part of the emission source to the nearest point of the potential receptor.

Standard cattle unit (SCU): A standard cattle unit is equivalent to an animal with a liveweight of 600 kg. Scaling factors to convert cattle of different weights to standard cattle unit equivalents are provided in the National Beef Cattle Feedlot Environmental Code of Practice (FLIAC 2012a).

Stocking density: Stocking density is a measure of the intensity with which a feedlot is stocked. In this document, stocking density is expressed in terms of an area (m^2) per standard cattle unit. Refer to the National Beef Cattle Feedlot Environmental Code of Practice (FLIAC 2012a) for information on determining stocking densities.

Surface water: Water on the surface of the land.

Sustainable: Able to be maintained in perpetuity.

Sustainable utilisation: Use of a resource so that it may yield the greatest continuous benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations.

Tailwater: Runoff from an irrigation area which arises when irrigation water is applied in excess of the infiltration capacity of the soil.

Terminal pond: A pond located at the end of an effluent irrigation area. It is intended to capture the initial and possibly heavily polluted runoff from a storm event. It is also intended to capture and hold tailwater generated by effluent irrigation systems.

Total solids (TS): see *Dry matter.*

Utilisation area: An area of land to which manure or effluent is applied.

Volatile solids (VS): Volatile solids are the organic compounds removed from a dry matter sample burned at 440°C (ASTM) or 550°C (ALPHA 1989) or 750°C (ASTM).

Watercourse: A watercourse is a permanent, intermittent or ephemeral stream shown on an official 1:100,000 topographic map. Alternative definitions may apply in state and federal legislation.