finalreport

FEEDLOTS

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Identifying & Assessing the Potential Transfer of Contaminants from Feedlot Waste Products

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EXECUTIVE SUMMARY

Meat and Livestock Australia (MLA) has identified the need for cost effective, practical management recommendations for the treatment and handling of manure and effluent for the intensive livestock and processing industries. Before any recommendations can be made however, the industry needs to collect further information, particularly with respect to the impact of waste treatment and application practices on human and animal health.

This project combined two studies FLOT.216 "An evaluation of the risk of the potential transfer of contaminants from waste products from intensive cattle and sheep industries" and FLOT.217 "Identifying waste management practices in intensive cattle and sheep industries to minimise the potential transfer of contaminants".

The objectives to be addressed within the project were to:
1. Provide a risk assessment for the potential transfer of contaminants from treated animal wastes; and
2. Identify and evaluate current industry practice for the treatment of waste products, and the requirements of the end use industries with regard to contaminants.

The focus of the project was on the feedlot industry only. The project team investigated products/contaminants likely to have a human or animal health effect. Products or applications with an environmental focus (eg. rehabilitation of land, forestry) were not covered. The range of risks to be identified and assessed included zoonotic diseases, pathogens, heavy metals, viruses and parasites.

Identification of end products and use

Waste products that feedlots produce (or could produce) are non-composted solids, composted solids, pelletised manure, vermicompost and liquid effluent for irrigation. Use of waste products within the feedlot includes irrigation and fertilising silage crops. Outside the feedlot uses for waste (after sale) include products such as fertiliser and soil conditioner used in the nursery, landscaping, horticulture and agricultural industries.

Implications for human health include contraction of zoonotic diseases, contamination of water supplies (recreational and drinking water), production of contaminated aerosols, and contamination of plant products or other crops consumed by humans. Potential contaminants include pathogens, heavy metals, and chemical residues.

Implications for animal health include contraction of infectious and foodborne disease and contamination of water supplies.

Contaminants

A literature review was undertaken to assess the likely contaminants present in feedlot waste products. For each contaminant, information was collected on:
- Background level in bovine waste
- Infectious dose
- The disease in humans and cattle
- Outbreaks associated with the causal agent and waste products
- Exposure (transport and dissemination)
- Survival of the causal agent in feedlot waste products
- Overall potential threat.

Potential contaminants were identified as

- *Campylobacter jejuni/coli* (thermotolerant Campylobacters)
- Shiga-toxin producing *Escherichia coli* (STEC)
- Salmonella spp
- *Coxiella burnetii*
- *Leptospira* spp
- *Listeria* spp
- *Yersinia* spp
- *Clostridium* spp
- *Mycobacterium* spp
- *Mycotoxins* spp
- Other - Brucellosis, Anthrax, Shigella and *Vibrio cholerae*
- Cryptosporidium
- Giardia
- Heavy Metals
- Chemical pesticides
- Hormones and endocrine disruptors
- Antibiotics and antibiotic resistant genes
- Antibiotic resistant enterococci

Risk Assessment

Based on the information collected in the literature review, and likely transfer paths, specific risks were identified and a semi-quantitative risk assessment was undertaken. Quantitative risk assessment was not possible because of the lack of data with respect to the actual levels of pathogens present and knowledge of how those pathogens are transported or disseminated.

The risk assessment considered the consequences and severity of adverse effects and the likelihood of contamination of the waste product. Animal and human health were considered separately, with animal health primarily focused on cattle.

Without considering feedlot best practice, or actual practices, the high risks were identified. For humans *E. coli* (STEC) is the contaminant of concern. For cattle, the causal agents of concern are Salmonella, Mycobacterium and Clostridium. Paths of transfer include contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking; contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals; and direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.

There were significant unknowns in the risk assessment, particularly with assessing risks associated with air-borne transmission. A definitive assessment could not be made on several causal agents and therefore can not totally be dismissed as no risk.

Feedlot Practices

Feedlot practices which impact on contaminant transfer include site plan/location of the feedlot, importation of new animals, routine management of cattle, removal of manure from pens and reuse of manure and wastewater. Best practice methods were identified.

A survey of feedlots was conducted to determine their waste treatment methods. From the responses, a number of concerns with feedlot waste practices were identified, mainly relating

to the method of composting and the application of waste products. Without feedlots adopting risk management protocols, the potential for human and animal health problems as a result of feedlot waste management and disposal practices appear significant. There is an urgent need to supply feedlots with information which will minimise these risks by assisting them to implement risk management protocols within their operations.

Issues with current feedlot practices include:

- The end use of waste products was of concern in many instances (eg use of non-composted feedlot solids for minimally processed food).
- The method of composting. Composted product could not be considered as being produced from feedlots that only composted for short periods (eg 10 days) and neither watered or turned their compost piles.
- The safety and stability of composted product was not demonstrated by most feedlots.
- Few risk reduction strategies were nominated by feedlots.

Programs, Codes, Standards and Legislation

Feedlot waste products and practices impacting on contaminants are covered by many codes, standards, legislative requirements and guidelines. There is a concern however, that these may be imposing too many restrictions on the feedlot industry.

The Australian Standard for composts, soil conditioners and mulches (AS4454-1999) was reviewed in detail. Two major issues were identified:

1. Compliance to national health standards and associated costs: The Standard requires that all materials should comply with the chemical and organic contaminant provisions of State or Federal guidelines (whichever is the more stringent). While this is necessary for human and other waste products, chemical contaminants in feedlot waste are likely to be very low and therefore the cost of complying seems unnecessarily high.
2. Concern with regrowth of pathogens: The Standard does not refer to the problems associated with pathogen regrowth in composts which can occur if the compost is not of biological maturity. The Standard recommends a composting time of six weeks rather than testing for maturity.

The AFFA food safety guideline for fresh produce is another guideline of relevance to feedlots supplying waste to the horticultural industry and should be used as an overall risk minimisation strategy for feedlots supplying this market.

End Users

Most end users of waste products produced by the feedlot industry are adhering to an industry guideline, code or AS 4454-1999. With the recent push towards HACCP based quality systems, the majority of final end users (eg supermarkets) only require that the grower (eg horticulturalist) be able to demonstrate the safety of the product application.

Risk Minimisation

Risk minimisation strategies which have been identified within the project are summarised as follows:

- Catch runoff from the feedlot in drains, and store in a holding pond. The implementation of appropriately sized vegetated buffer strips adjacent to water courses and water wells or bores will reduce the potential risk of contamination even further.
- Maintain a vegetated buffer strips onto which no manure or effluent is applied, to minimise the likelihood of groundwater and surface water course contamination when effluent is applied to pastures and crops.
- View recently arrived cattle as a source of infection for the feedlot, adding to increased loading of pathogens in waste.
- For recently arrived cattle to undergo a vaccination program and therapeutic treatment with antibiotics or other pesticides
- Ensure the quality of incoming feed.
- Set limits on the acceptable level of heavy metal contaminants present in supplies of limestone and phosphate added to feed formulations.
- Ensure the addition of trace mineral supplements is strictly in accordance to cattle requirements.
- Prevent workers inhaling contaminated dust or fluid droplets (aerosols), exercise good personal hygiene, and cover cuts and abrasions with water-proof dressings.
- Vaccinate workers against Q fever, and vaccinate cattle against leptospirosis to reduce the risk of workers contracting these diseases.
- Undertake customer end use analysis (ie development of waste-use specifications) and regularly update to ensure waste products are sufficiently treated to minimise the risk of contaminant transfer to final consumers. Feedlots must carefully consider the end market when supplying waste products, in particular only supplying materials to certain markets which have been sufficiently treated to minimise pathogen presence.

HACCP would be a highly effective tool in implementing risk management guidelines. Using the risks identified within this project, feedlots can determine their individual risk based on best practice guidelines. A risk minimisation program for feedlots should consist of several elements:

1. Guidelines based on sound science and communication of these guidelines to the feedlot industry.
2. A HACCP plan for each feedlot based on the risk assessment in this report (eg through the NFAS program). This will more than sufficiently meet the needs of end users and could be used as an alternative to the AS4454.
3. Monitoring of conditions that might promote pathogen growth at the individual feedlot level, coupled with a wider industry program to demonstrate baseline levels of pathogens and heavy metals in waste.

Conclusions and Recommendations

In conclusion, several contaminants and practices were assessed as being of extreme concern to the industry in terms of animal and human health. Current waste management practices appear to be placing the industry at greater risk and composting techniques are questionable. It is clear that industry education is required.

In reviewing legislation, codes, standards and guidelines, there are many conflicting and confusing guidelines. The AS4454 puts an unnecessary impost on industry in terms of testing, but may not sufficiently reduce risks to an acceptable level (pathogen regrowth). The other guideline of interest to the feedlot industry is the recently released "AFFA on-farm food safety guidelines for fresh produce".

Measurement and analytical techniques for specific contaminants are costly and unnecessary. Instead, as part of an overall HACCP and risk minimisation program, monitoring of the safety of feedlot waste products should include a monitoring of time-temperature parameters (in composting) and testing for an indicator organism such as faecal coliforms.

The following recommendations have been made:

1. Research should be undertaken to quantify levels of pathogens in feedlot waste so that more accurate guidelines on waste treatment methods for feedlots can be produced (eg time-temperature guidelines for composts).
2. Feedlots should undertake a customer end use analysis and discontinue supplying inappropriate waste products to markets where an identified risk exists.
3. Using the risk management strategies and other information collected in this report, waste management guidelines should be developed
4. An industry communication strategy should be developed to ensure all feedlots are kept up to safe on best practices for the management and use of feedlot waste products.
5. Every feedlot should develop its own risk minimisation program based on HACCP that could be incorporated and administered as part of the NFAS program. The plan should include a requirement to monitor conditions that might promote pathogen growth in waste products.
6. Industry should consider establishing baseline levels of pathogens and heavy metals to reduce the requirement of feedlots to incur on-going tests. Results should also be used in providing evidence to Standards Australia for support in reducing the feedlot testing requirements of AS 4454 .
7. Industry to contact Standards Australia to express concern regarding AS4454, in particular pathogen regrowth and testing requirements.

1. INTRODUCTION

Meat and Livestock Australia (MLA) identified the need for cost effective, practical management recommendations for the treatment and handling of manure and effluent for the intensive livestock and processing industries. However, there is a need for more information to be gathered before these recommendations can be made.

Two projects were designed to address this need:

- (FLOT.216) An evaluation of the risk of the potential transfer of contaminants from waste products from intensive cattle and sheep industries. This project was to identify and assess the risk that animal wastes pose to human and animal health, and impact of these wastes on end user production systems (contaminants are defined as infectious agents (bacteria, viruses, parasites), heavy metals, chemicals, seeds and other hazards).
- (FLOT.217) Identifying waste management practices in intensive cattle and sheep industries to minimise the potential transfer of contaminants. This project will identify and document the management/treatment procedures required to achieve a "safe" product for sale from specific livestock industries, for the differing target markets.

Due to efficiencies in data and research collection, both projects were combined into one and a desk-top study undertaken. This report details the result of the study.

2. OBJECTIVES

The objectives of the two projects were:

FLOT.216: To provide a risk assessment for the potential transfer of contaminants from treated animal wastes.

1. Identify the contaminants most likely to be transferred from treated animal waste products to humans, animals and end user production systems, which are a potential threat.
2. Identify and evaluate the qualitative and quantitative measurement and analytical techniques for the contaminants identified in (1) and the perceived limitations of those techniques as a monitor of QA.
3. Identify and document incidents where contaminants have been transferred from treated animal waste causing illness.
4. Based on current best practice for treatment of animal wastes, assess the risk of transfer of contaminants from treated animal waste products to humans, animals and end user production systems.
5. Comment on the adequacy of current Australian standards.

FLOT.217: To identify and evaluate current industry practice for the treatment of waste products, and the requirements of the end use industries with regard to contaminants.

6. Identify the current waste management practices being undertaken by the intensive cattle industry (feedlots), abattoirs and rendering plants. This was

needed to address the potential transfer of contaminants to the end product, and should include, but not be limited to the following:
(a) Treatment procedure and cost
(b) Measurement, recording and documentation practices
(c) Intended market for the end product
(d) Requirements of the end user and the scientific rationale for the same
(e) Risk reduction strategies as they relate to contaminants.

7. Provide an evaluation of the practices identified in (6) with respect to "fitness for purpose", and to the Australian Standard (AS 4454-199) for composts, soil conditioners and mulches with regard to the contaminant status of the end product.

8. Identify any perceived/real concerns by end users of waste products with regard to the potential for transfer of contaminants from the end product to humans or livestock. This was to address any conditions of sale requiring a lag time between application of the waste product and sale of goods, or recommended/regulated withholding periods, and the scientific evidence supporting the concerns, and ultimate recommendations.

3. SCOPE

Following discussion with MLA, the scope of the project was redefined prior to the project start to the following elements:

- The focus of the project was to be on the feedlot industry, although collection of information in relation to the processing sector was likely.
- Products/contaminants investigated were those likely to have a human or animal health effect, including those indirectly consumed or those which come into contact with humans and animals. The project looked at pulse crops, fruit and vegetables, effluent irrigation methods and composts, but products or applications with an environmental focus (eg. rehabilitation of land, forestry) were not covered.
- The range of risks to be identified and assessed included zoonotic diseases, pathogens, heavy metals, viruses and parasites.

4. PROJECT APPROACH

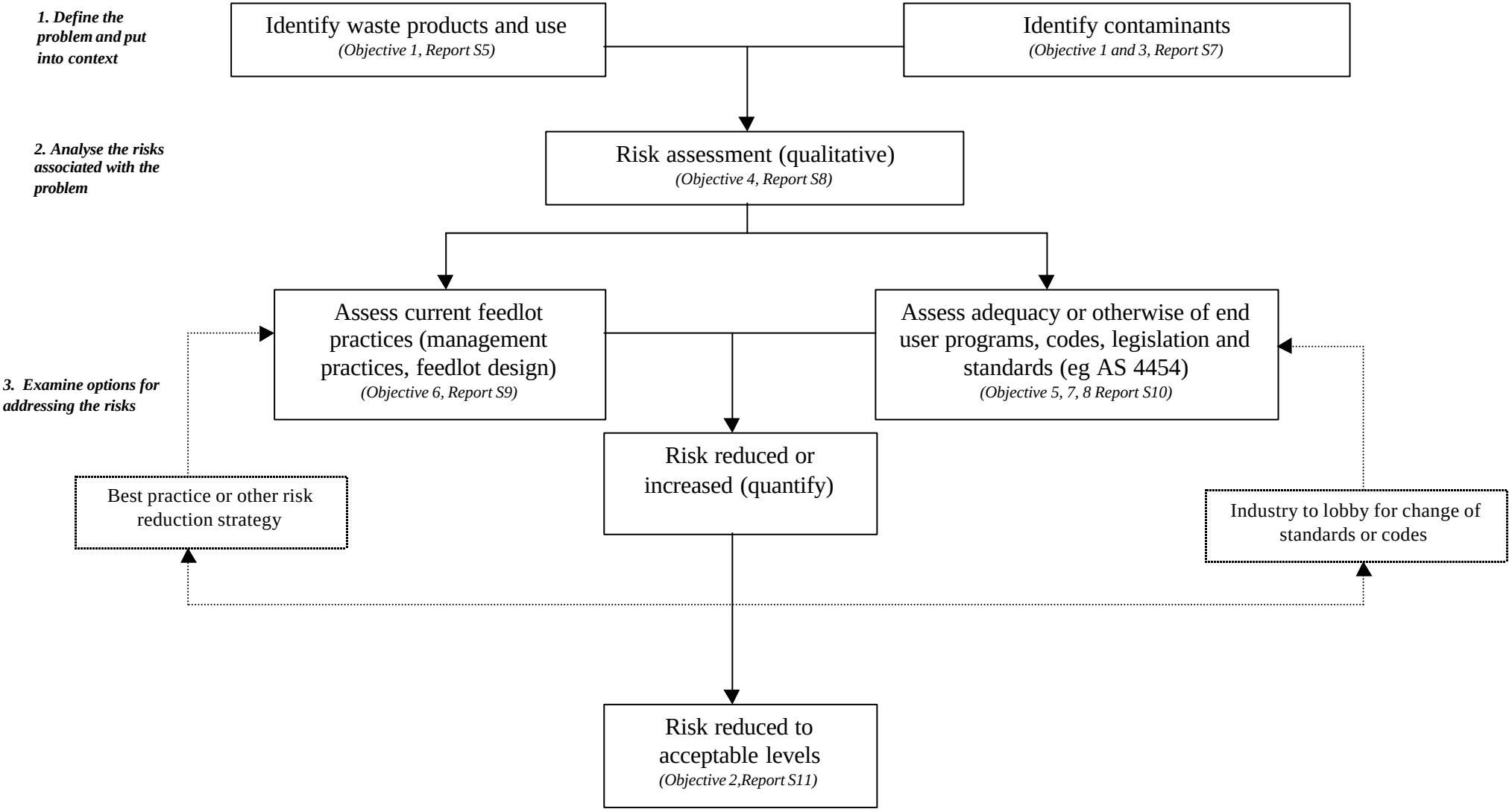
Risk assessment has been used in this project as a tool for the future development of a risk management plan able to reduce, mitigate or minimise the risk of waste product contaminants (practical management recommendations).

A framework for risk assessment and management consists of six stages (Powell, 1998):
1. Define the problem and put it into context
2. Analyse the risks associated with the problem
3. Examine options for addressing the risks

4. Make decisions about which options to implement
5. Take actions to implement the decision
6. Conduct an evaluation of the action's results.

This report has addressed the first three stages in this framework as represented in Figure 1. This representation also provides references to sections of this report and links to the relevant objective of the project.

FIGURE 1: PROJECT APPROACH BASED ON MANAGEMENT DECISIONS



5. FEEDLOT WASTE PRODUCTS AND USE

Manure constitutes the greatest category of waste produced within an operating feedlot. A typical 450 kg beast produces about 27 kg of manure each day, of which approximately 85 to 90% is water (DPI, 2000). Much of the water will evaporate from the pad, and some nitrogen will be lost as ammonia gas. However the solids in the manure accumulate on the pad, with an estimated 1-2 tonnes of manure per head needing to be removed on an annual basis. Manure may also be carried a substantial distance from pens and manure storage sites in run-off associated with storm events. Drains collect overland flow, channelling it into holding ponds or evaporation basins.

Waste from feedlots is composed of undigested organic matter, nutrients (nitrogen, phosphorus, potassium, sulphur) and water. The precise amounts vary between enterprise types and depend on the management systems used (Casey 2000). Nevertheless, feedlot waste is considered a good fertiliser and soil conditioner.

Waste products that feedlots produce (or could produce) are listed as follows:

- **Non-composted solids** are manure solids collected from pens but not specifically treated to render them free of harmful contaminants or weed seeds.

- **Composted solids** are solid wastes which have undergone a process to render them free of harmful pathogens and weed seeds. Several methods exist for composting.

- **Pelletised manure.** Pelleting involves reducing the water content and particle size of manure and compressing the material into cylinders of uniform length and diameter (Hadas *et al*, 1983). The resultant product stores readily, is less costly to transport, and can be more accurately broadcast or fed through conventional fertiliser application systems.

- **Vermicompost** is the waste products of earthworms excreted by some species at the manure surface.

- **Liquid effluent** is usually obtained from storm run off from pens held in evaporation or holding ponds.

6. TRANSFER ROUTES

A transfer route or exposure pathway is defined as the means by which an agent can cause animal or human health problems. It is a physical route and is dependent on individual feedlot management practices (eg design and siting, removal and stockpiling of manure and retention of stormwater). These will be detailed further in Section 8 of this report.

Transfer routes of relevance to this study are detailed in Table 1.

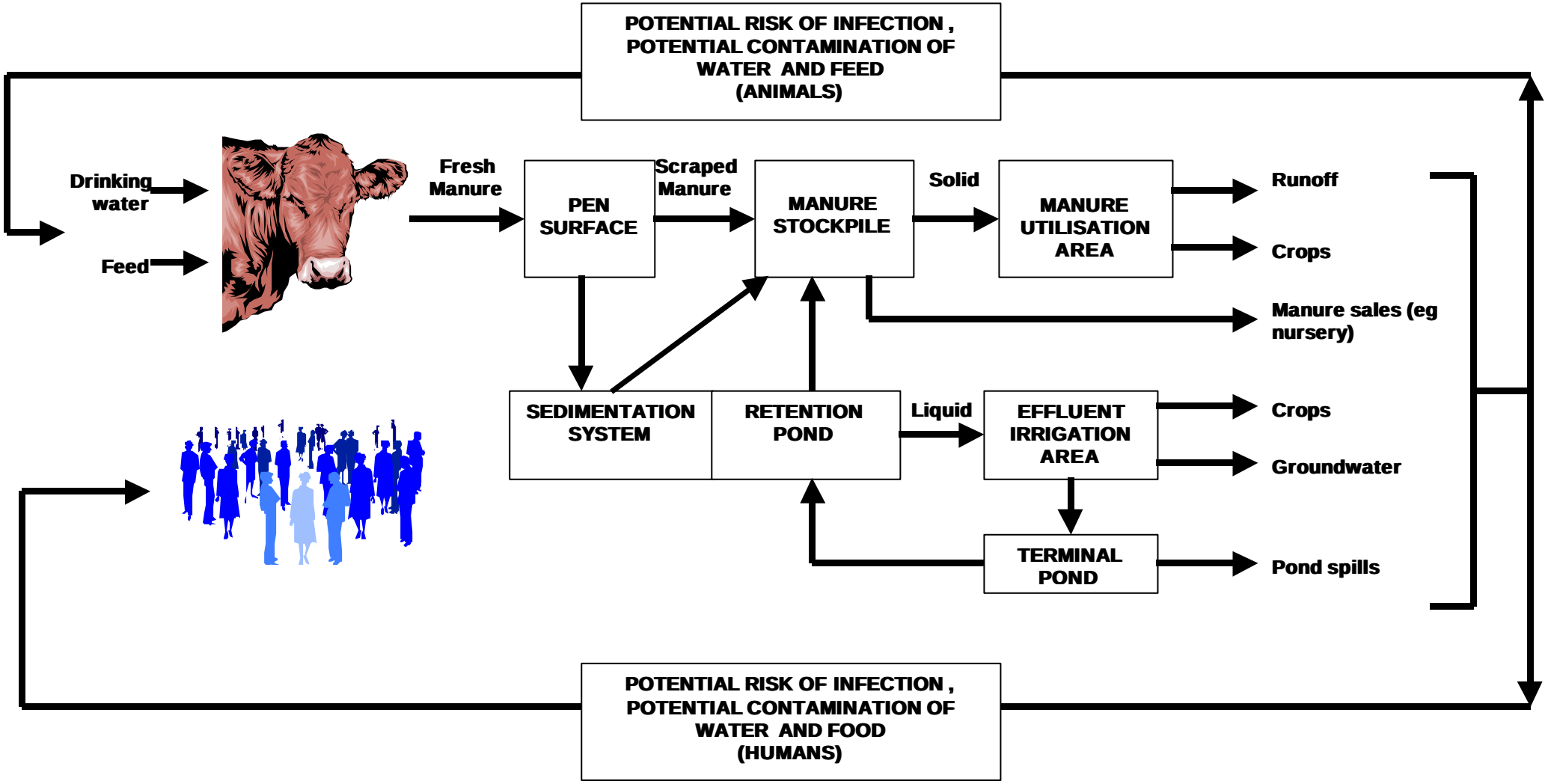
TABLE 1: CONTAMINATION TRANSFER ROUTES OF FEEDLOT WASTE PRODUCTS

The transfer path/exposure pathway	Who/what is exposed
Inhalation or ingestion of windblown particles from waste applied to agriculture land.	▪ Worker applying the waste ▪ People living or working within proximity to application ▪ Grazing, wild or domestic animals.
Inhalation or ingestion of windblown particles from waste stored at the feedlot.	▪ Feedlot workers ▪ Visitors ▪ Feedlot cattle, working horses or other animals within the feedlot boundary.
Run-off from holding ponds, evaporation basins, solid waste holding facilities or truck washing into waterways used for non-agricultural purposes	▪ Recreational swimmers ▪ People or animals drinking from the waterway
Run-off from holding ponds, evaporation basins, solid waste holding facilities or truck washing into waterways used for agricultural purposes (eg irrigation of crops, pasture lands, supply of water to animals)	▪ People or animals consuming crops ▪ People consuming meat or milk from cattle or other animals grazing on potentially contaminated land ▪ Animals from the drinking water
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	▪ People or animals consuming crops. ▪ Consumption of meat or milk from cattle or other animals grazing on potentially contaminated land. ▪ Cattle or other animals grazing forage, crops or pasture.
Direct contact with contamination in end product such as fertiliser and soil conditioners.	▪ Nursery, landscaping, horticultural, agricultural and domestic consumers.

The distribution of feedlot waste within a feedlot is represented in Figure 2 (adapted from Casey 2000). This links feedlot waste production to animal or human exposure and therefore represents possible contamination paths.

In summary, the implications for human health include contraction of zoonotic diseases, contamination of water supplies (recreational and drinking water), production of contaminated aerosol, and contamination of plant products consumed by humans. Potential contaminants include pathogens, heavy metals, and chemical residues. Implications for animal health include contraction of infectious and foodborne disease and contamination of water supplies.

FIGURE 2: FEEDLOT WASTE USAGE (WITHIN THE FEEDLOT BOUNDARY)



7. CONTAMINANTS (CAUSAL AGENTS)

A full literature review of possible contaminants which may be present in feedlot waste and cause harm to animals or humans was conducted. Potential contaminants were grouped according to bacteria and fungi, parasitic protozoa and chemical contaminants. Antibiotic resistance of microorganisms has been incorporated under chemical contaminants due to the likely cause being a chemical itself.

For each potential contaminant, detailed research findings were presented in the following categories. These categories were chosen as appropriate for conducting a quantitative microbial risk assessment if data were available.

1. **Background levels in the bovine waste** - This details the presence of an agent in bovine waste or waste products. Where possible, Australian data have been sourced.

2. **Infectious dose** – For pathogenic bacteria, the simple presence does not necessarily mean that infection will result. The pathogen must be present at high enough numbers to ensure that an infection will result. This is quantified as the ID_{50} or the number of organisms needed to ensure that 50% of the exposed population are infected.

3. **The disease in humans and cattle** - The effect of the contaminant on humans and/or animals is important in assessing the likely risk. A serious disease will obviously have a greater impact in terms of consequences (therefore making it a greater risk if it happened).

4. **Outbreaks associated with the causal agent and waste products** – A review of the outbreaks worldwide that were or may have been associated with a waste product.

5. **Exposure (transport and dissemination)** - While the contaminant may be present in a waste product, the possible route by which it reaches the end consumer or animal needs to be assessed. Transfer paths were identified in Section 6 of this document and have not been repeated here. In general, for all agents, the exposure route is oral (eg by eating, inhalation) but for chemicals may also occur subcutaneously.

6. **Survival of the causal agent in feedlot waste products** - How the causal agent survives in the waste product under various application and treatment processes will impact on the overall threat of the agent.

A summary of all these factors is made when undertaking the risk assessment (refer Appendix 1).

7.1 BACTERIA AND FUNGI

7.1.1 *Campylobacter jejuni/coli* (thermotolerant Campylobacters)

7.1.1.1 Background levels in bovine waste

A recent MLA Report (Vanselow & Hornitzky, 2001) found that all feedlots yielded Campylobacter from some faecal samples with positive rates on individual feedlots varying from 10 to 90% of affected cattle. In a separate study, prevalence of less than 50% in cattle was found (Grau, 1988). It is likely that this study from the 1980s underestimated the true prevalence as indicated above. No enumeration of numbers of *C. jejuni/coli* has been made in Australia.

A United Kingdom (UK) study showed that 89.4% of beef cattle carried *C. jejuni/coli (*Stanley *et al*, 1998a). This same study showed the average and peak levels in cattle varied with both the type (beef compared dairy) and age (Table 2) (adapted from Stanley *et al*, 1998a).

TABLE 2: LEVELS OF *C. JEJUNI*/COLI IN BEEF CATTLE

Animal	Average MPN /g fresh faeces	Peak MPN /g fresh faeces
Beef cattle at slaughter	6.1×10^2	2.4×10^7
Dairy cattle	69	ND
Calves	3.3×10^4	2.4×10^8

MPN: Most probable number
ND: Not determined.

Bolton *et al*, 1982, reported lower prevalence levels in cattle (eg 20%) in the UK. The higher levels encountered in recent studies are believed to be due to better cultivation/isolation methods (Stanley *et al*, 1998a) suggesting differences over time are not in fact real.

There is evidence for seasonal variation in the numbers of *C. jejuni/coli* in dairy cattle but not in beef cattle (Stanley *et al*, 1998a).

7.1.1.2 Infectious dose

500-900 organisms. In an outbreak in England caused by wild bird droppings contaminating a potable water tank, the minimum infection dose for humans was determined as 500 viable cells (Nicholson *et al*, 2000).

7.1.1.3 The disease in humans and cattle

A major cause of human gastro-enteritis, *C. enteritis* is the most common notifiable infection in humans in Australia, with more than 10,000 cases of Campylobacteriosis being reported each year since 1994 (Anonymous, 2001a). Disease attributable to gastrointestinal infection by Campylobacter are characterised by diarrhoea, fever, abdominal pain and sometimes bloody diarrhoea. It has lower hospitilisation and fatality rates than that of salmonellosis (Vanselow & Hornitzky, 2001).

Campylobacter do not adversely affect animal health and it is impossible to know when animals are shedding the pathogens. It is regarded as normal flora in adult cattle although there is some evidence that *C. jejuni/coli* may be associated with enteritis type conditions in young animals (Radostits *et al*, 2000).

7.1.1.4 Outbreaks associated with the causal agent and waste products

Campylobacter have been implicated in disease outbreaks associated with the contamination of groundwater drinking supplies (Goss *et al*, 1998; Jones, 1999; Stanley *et al*, 1998c).

No human or animal outbreaks of Campylobacter associated with waste products were found in the literature.

7.1.1.5 Exposure (transport and dissemination)

The exposure route for infection by Campylobacter is generally oral. Campylobacter could be present on crops or food products as a result of irrigation or fertilisation with feedlot waste product and could be subsequently ingested by consumers or animals.

Likewise, contamination of groundwater or bore water supplies may occur during run-off either from stockpiles, pens or pastures if waste containing Campylobacter is present.

Feedlot workers may be at risk if handling manure or run-off without proper personal hygiene measures.

7.1.1.6 Survival of the causal agent in feedlot waste products

C. jejuni is widely regarded as a fragile organism that is susceptible to a number of environmental stresses (Nicholson *et al*, 2000). Yet, prolonged survival of this organism in the aquatic environment has been demonstrated eg. 40 – 60 days in sterile river water held at 15°C (Thomas *et al*, 1999).

In general there is little knowledge of the survival of *C. jejuni* in bovine manure. Studies in the UK have shown that aeration of stored dairy slurry caused a drop in Campylobacter from 363 colony forming units (CFU)/g to 128 CFU/g (Stanley *et al*, 1998a).

In the UK, Campylobacter could not be detected in soil that received dairy cattle slurry (with only a low level of Campylobacter) after 24 hours in summer (Stanley *et al*, 1998b). In winter, application of slurry resulted in detectable Campylobacter for up to five days and 20 days (Stanley *et al*, 1998b). The latter figure of 20 days would appear to be the maximum that could be expected as the conditions (low temperature and high rainfall) would appear to have been optimal for survival of Campylobacter.

Research in progress in the US using three one ton manure piles is studying the survival of enteric pathogens (Campylobacter, *Salmonella dublin, Escherichia coli* O157:H7, *Listeria monocytogenes*, *Cryptosporidium parvum* and an index organism, *Enterococcus faecalis*) during the summer and winter. After two months of data collection, the *C. jejuni* had died out within 3 days and other pathogens were decreasing in quantity each month (USDA, 2000).

No Australian studies on the survival of Campylobacter in bovine faeces, bovine manure or soil that has received bovine manure have been found.

7.1.2 Enterohaemorrhagic *Escherichia coli*

Table 3 classifies the *E. coli* pathogens into five classes (Vanselow & Hornitzky 2001). For the purpose of this review, we will focus on the STEC to refer to those *E. coli* that produce Shiga toxins and which are isolated from animals. The STEC isolates associated with human disease are a specific subset that we will term EHEC - enterohaemorrhagic *E. coli.*

TABLE 3: THE FIVE CLASSES OF ENTERIC *E. COLI* PATHOGENS (ADAPTED FROM VANSELOW & HORNITZKY 2001(SOURCED FROM NATARO AND LEVINE, 1994)

Abbreviation	*E. coli*	Description
EPEC	The enteropathogenic *E. coli*	Cause a syndrome of watery diarrhoea, vomiting and fever in infants and young children.
ETEC	The enterotoxigenic *E. coli*	A major cause of diarrhoea in infants and young children in less-developed countries; in persons from industrialised countries who travel to less-developed areas; and in neonatal herd animals including piglets, lambs and calves.
EIEC	The enteroinvasive *E. coli*	Closely resemble *Shigella* in biochemical reactions, virulence properties, pathogenic mechanisms and the clinical illness produced.
VTEC	The verotoxigenic *E. coli*	These are similar to EHEC but to not have the ability to adhere to the intestine

Abbreviation	*E. coli*	Description
= STEC	= The Shiga-like toxin producing *E. coli*	and are not as pathogenic as EHEC.
sub-class EHEC	The enterohaemorrhagic *E. coli*	These have been associated with epidemic and endemic diarrhoea, haemorrhagic colitis and haemolytic uraemic syndrome.
EGEC	The enteroaggregative *E.coli*	Shown to cause watery diarrhoea in volunteer studies.

7.1.2.1 Background levels in bovine waste

In the USA, the most common STEC and EHEC isolates have been serotype O157. However, in Australia, serotype O157 has been less important in human disease – isolates of serovars O111 and O26 have been more commonly associated with disease (Robins-Browne *et al*, 1998).

Australian studies have focussed on STEC rather than just *E. coli* O157. STEC were found in 16.7% of dairy cattle faeces and 4.1% of environmental samples (Cobbold & Desmarchelier, 2000). Calves at weaning are the most likely group to be shedding STEC (Cobbold & Desmarchelier, 2000).

In a Queensland beef feedlot, 18% of 750 faecal samples collected over a 72 day period were positive by genetic methods for the Shiga-toxin gene and 5% were culture positive (Midgley & Desmarchelier, 2001). In this same study, 7 of 16 soil samples were positive for Shiga-toxin genes and two of the 16 samples yielded STEC (Midgley & Desmarchelier, 2001). Midgley & Desmarchelier (2001) have concluded that STEC is endemic in beef cattle and that intermittent peaks in shedding occur.

Vanselow & Hornitzky (2001) found 14% (4/29) of feedlot faecal samples contained positive STEC. The serotypes were identified as O2:H29, O157:H7, Ont:H- and Ont:H14. In a second phase of testing, a selection of feedlot cattle were sampled at the time of entry, one month later and preslaughter. Serotypes identified included one sample each of O6:H28 and O113, four samples of O113:H21 and two samples of O130:H11. Drinking water samples were also collected in this study, with two feedlots recording positive samples.

Studies in the US have reported between 0 to 2.2% of cattle are positive for *E. coli* O157 (Dargatz *et al*, 1997). In the UK, *E. coli* O157 has been found in 0.25% to 4% of animals (Dargatz *et al*, 1997 and Robins-Browne *et al*, 1998).

7.1.2.2 Infectious dose

A review of the literature found a wide variance in infectious doses for EHEC strains associated with human disease, ranging from 1 organism to 10^8 organisms.

7.1.2.3 The disease in humans and cattle

E. coli disease in man is usually due to strains only associated with man. In recent years there has been the emergence in humans of particular subtypes, EHEC (enterohaemorrhagic *E. coli*), often also called VTEC (verotoxin producing *E. coli*) or STEC (shiga-toxin producing *E. coli*) strains that are associated with animal sources. The best known of these EHEC strains is the O157 type that has caused frequent problems in the USA (Gray, 1995). These strains can cause serious conditions such as haemolytic urealytic syndrome (HUS) (Gray, 1995) and death in the immunocompromised.

The effect of *E. coli* in cattle is non-pathogenic in adult cattle as (Armstrong et al (1996))

7.1.2.4 Outbreaks associated with the causal agent and waste products

In 1991 an outbreak of *E. coli* O157:H7 infections (23 cases) in Massachusetts was associated with consumption of cider prepared from a cider mill. Ninety percent of the apples used in the cider were ‘drops’, apples collected from the ground (De Roever, 1998).

Recent outbreaks of E. coli O157:H7 have been associated with organically produced sprouts and lettuce. Generic E. coli was found in 16.7% of organic lettuce mix and 8.3% of non-organic (Doyle, 2000).

The most recent incident linked to manure was in Ontario in the Spring of 2000, where seven people in Walkerton died and 2300 fell ill after drinking water contaminated with *E. coli* O157:H7. The series of events surrounding this incident is still being investigated, with most of the blame being directed at the insufficient treatment of the water. However, the source was thought to be farm manure which washed into one of the town's wells (Powell, 2000).

The largest recorded foodborne outbreak of enterohaemorrhagic *E. coli* causally associated with the ingestion of radish sprouts, involved 6000 confirmed cases in Japan. In one of the three sprout outbreaks documented, seed contamination was traced back to alfalfa fields located directly adjacent to feedlots, and to irrigation water contaminated with cow and deer manure (Powell, 2000).

Like Campylobacter, *E. coli* has also been implicated in disease outbreaks associated with the contamination of groundwater drinking supplies (Goss *et al*, 1998; Jones 1999; and Stanley *et al*, 1998c).

7.1.2.5 Survival of the causal agent associated with waste products

There appear to have been no Australian studies on the survival of STEC in bovine faeces, bovine manure or soil that has received bovine manure. However, the Elizabeth Macarthur Agricultural Institute of NSW Agriculture has conducted research for Sydney Water on the survival and growth of pathogenic bacteria after agricultural application of human waste containing *Salmonella* sp, *Escherichia coli* and *Clostridium perfingens*. These studies done by Eamens et al, 2001 applied biosolids to agricultural land at two sites. From the first study, it was found that agricultural land which received lagooned biosolids was likely to reach baseline levels for *E. coli* in 4-5 months. Those that received dewatered biosolids took at least a further 1-2 months to reach the same level.

In the second study (Eamens, unpublished), survival of *E. coli* was quite prolonged as shown in Figures 3 and 4, in excess of 60 weeks in some instances.

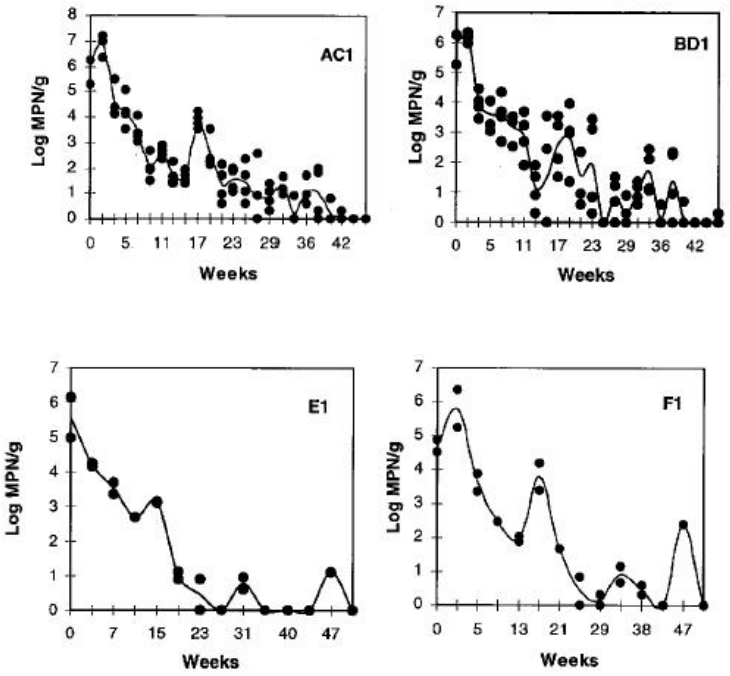


Figure 3. *E. coli* die-off in biosolids in Goulburn 1 plots (AC = incorporated; BD = surface applied) treated with 10 or 30 dry t/ha of biosolids. Comparative results are provided for two paddock applications (El, Fl = 30 dry t/ha surface applied). Separate points at each sampling represent result for each duplicate sample taken. A single dot at a particular time point indicates counts for each duplicate were equal.

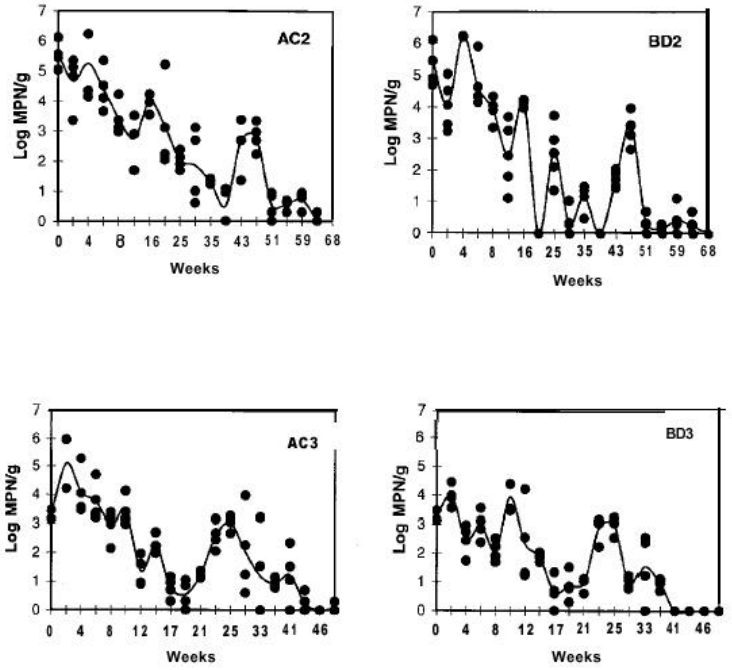


Figure 4: *E. coli* die-off in biosolids in Goulburn 2 and Goulburn 3 plots, shown as the mean concentration in biosolids for 2 plots given either incorporated biosolids (AC) or surface applied biosolids (BD). Results for the two application rates (10 or 30 dry t/ha) have been pooled. Separate points represent results of each duplicate sample tested at each time point. A single dot at a particular time point indicates counts for each duplicate were equal.

Survival studies on STEC have also been performed in the USA and Europe. As *E. coli* O157 is the dominant serovar of STEC in these locations, these studies have all featured this organism. There is little if any knowledge on the survival of the other serovars of STEC. Results of these studies are provided below:

- In the USA, *E. coli* O157 survived in bovine manure heaps that were aerated for 47 days (Kudva *et al*, 1998). The manure was sourced from cattle experimentally infected with *E. coli* O157. In laboratory experiments using spiked manure and slurry held at a range of temperatures, *E. coli* O157 survived best at temperatures below 23°C and survival times were generally shorter (generally 24 hours to 40 days) than found in the field manure piles in the environment (Kudva *et al*, 1998). These results are very similar to an earlier USA study that found *E. coli* O157 survived for up to 49 days in bovine faeces held at 37°C (Wang *et al*, 1996).

- In a series of experiments in which bovine manure or bovine slurry were spiked with *E. coli* O157 and then held at 4°C, 20°C and 37°C, researchers in the USA calculated the time for a 90% reduction – termed the decimal reduction time (Himathongkham *et al*, 1999). The key findings of this study are shown in Table 4.

TABLE 4: *E. COLI* O157 DESTRUCTION RATE IN CATTLE MANURES STORED AT DIFFERENT TEMPERATURES

Storage temp. (°C)	Manure type	Manure heap location	Decimal reduction time* (d)
4	Manure	Top	9.04
4	Manure	Mean (middle and bottom)	18.59
4	Slurry	ND	21.50
20	Manure	Top	21.60
20	Manure	Mean (middle and bottom)	13.51
20	Slurry	ND	14.70
37	Manure	Top	8.91
37	Manure	Mean (middle and bottom)	3.58
37	Slurry	ND	3.10

*Time required to achieve a 1 log reduction in pathogen numbers

ND = not determined

- The data generated by Himathongkham *et al*, 1999, can be used in a risk assessment approach for setting guidelines eg if it is decided that a $\geq 10^5$ reduction in *E. coli* O157 is needed, then manure should be held at 93 days at 4°C or 45 days at 37°C. The study of Himathongkham *et al*, 1999 was a laboratory-based study so there may be some limitations to its application in the field.

- In the UK, slurry samples spiked with *E. coli* O157 at 6.0×10^6 cfu/g were still positive after 12 weeks storage at 10°C (McGee *et al*, 2001). The log reduction recorded in this study over the 12 weeks varied between 3.5 to 5.5 (McGee *et al*, 2001). The spiking level was at the high end of the expected natural levels in cattle faeces (McGee *et al*, 2001).

- A recent study in the UK concluded that *E. coli* and *E. coli* O157 show a similar die-off in the environment indicating that die-off studies can be performed on the total *E. coli* population and the conclusions extrapolated to *E. coli* O157 (Ogden *et al*, 2001).

- Soil survival studies in the UK have indicated that *E. coli* can be recovered for up to 5 weeks after application of dairy cattle slurry (Ogden *et al*, 2001). When soil core samples from the field study were taken and then held in the laboratory at 6°C and 15°C, the *E. coli* and *E. coli* O157 counts were less than 100 organisms/g within 18-24 days storage (initial levels in the slurry were 10^5CFU/g of *E. coli* and 30 cfu/100 g of *E. coli* O157) (Ogden *et al*, 2001).

- In another UK study, cattle faeces spiked with a high level of *E. coli* O157 (10^{8-9} CFU/g) was spread onto grazing land (Bolton *et al*, 1999). While there was a 5 log reduction within 50 days, *E. coli* O157 was still detectable after 99 days (Bolton *et al*, 1999).

- *E. coli* O157:H7 can remain viable for greater than 12 months in non-aerated cattle manure (Jones, 1999).

- In the US, *E. coli* survived for up to 19 weeks following application of bovine manure to either silty clay loam or loamy sand (Lau & Ingham, 2001). There was only a slow decline in *E. coli* numbers of about log 1-2 over the 19 week observation period (Lau & Ingham, 2001).

- *E. coli* O157:H7 survived for about 30 days in soil alone (either treated with manure or not) but for about 60 days when the soil was planted with rye (Gagliardi & Karns, 2000)

- In bench-scale composting systems, researchers seeded *E. coli* O157:H7 and *Salmonella enteritidis* at a level of log 7 cfu/g of raw compost feed. *E. coli* O157:H7 was not detected after 72 h of composting at 45°C and *S. enteritidis* was not detected after 48 hours. No change in bacterial numbers were detected when the composting system was held at room temperature (Lung *et al*, 2001)

- Top dressing a spray-irrigated pasture of orchard grass with 125 t/ha of overwintered beef feedlot manure almost doubled the yield of dry forage. Even at this rate of application, the manure did not contaminate the grass with enteropathogenic bacteria after irrigation. The grass became contaminated through the use of faecally polluted irrigation water but the faecal coliforms were effectively eliminated from the grass after exposure to 65 hours of bright sunlight. (Bell *et al*, 1976)

- An *E. coli* O157:H7 positive bovine manure pile was culture positive for 47 days. In the laboratory, *E. coli* O157:H7 survived best in manure incubated without aeration at temperatures below 23°C but is usually survived for shorter periods of time than it survived in manure held in the environment (Kudva *et al*, 1998).

- Standard methods for seed disinfection in the sprouts industry do not adequately reduce the population of EHEC *E. coli* on contaminated alfalfa sprouts (Taorimina & Beuchat, 1999). The pathogen can also survive on harvested, cold-stored lettuce for up to 15 days (Beuchat, 1999), and is capable of growing on sliced cucumbers, shredded lettuce, on cantaloupe and watermelon cubes, and in apple juice.

- A study on the transmission of *E. coli* O157:H7 to lettuce plants through spray and surface irrigation found that the pathogen persisted on 82% of plants for 20 days.

7.1.3 Salmonella spp.

7.1.3.1 Background levels in bovine waste

A recent MLA Report (Vanselow & Hornitzky, 2001) found that 13% of Australian feedlot cattle properties yielded at least one faecal sample positive for Salmonella.

For each year from 1996 to 2000, the three most common serovars of Salmonella identified in the 1139 cattle isolates examined by the Australian Salmonella Reference

Centre were Bovismorbificans, Typhimurium and Dublin (Davos, 2000). Over this same period, the most common serovar amongst the 9606 human isolates was Typhimurium. Serovar Bovismorbificans was in the top six serovars each year for the same period (Davos, 2000). Phage typing during 2000 of human and bovine isolates of serovar Bovismorbificans established that the most common human phage type (Type 26) was not present in 81 bovine isolates of this serovar.

Australian studies, performed in the 1980s, did not examine faeces but looked at rumen and mesenteric lymph nodes. The studies showed that around 50% of cattle at slaughter are positive (Samuel *et al*, 1980; Frost *et al*, 1988). The preliminary study of Frost *et al* (1988) suggested there was an increased level of *Salmonella* infection in cattle that were adjusting to a feedlot diet as compared with cattle that had been at the feedlot for some time. The work of Frost *et al* (1988) also found that 8/16 soil samples from a feedlot were positive for Salmonella.

In a 1975 study from the UK, 11% of 187 cattle slurries were positive for Salmonella, although the numbers were very low, typically less than one organism per g (Jones & Matthews, 1975). A more recent study in Canada found a very low level of positive Salmonella from cattle (1/1,247) faeces of Canadian cattle (Van Donkersgoed *et al*, 1999). Faeces from colonised cows were reported with 10^2 to10^7 Salmonella cfu/g of faeces (Himathongkham *et al*, 1999).

While there is a lack of detailed knowledge about the current situation in Australia, it could be that Australian cattle are showing the same trend as overseas cattle – a decrease in the level of Salmonella.

7.1.3.2 Infective dose range

A review of the literature found a wide variance in the infective dose, from 100 - 10^6 organisms depending on the source.

7.1.3.3 The disease in humans and cattle

Following the consumption of contaminated food, Salmonellosis symptoms of humans are typically acute gastro-enteritis (Gray, 1995). It is usually a self-limiting illness and fatalities are uncommon (Gray, 1995). The types of Salmonella that can cause typhoid fever are found in humans only.

Cattle also suffer from salmonellosis with death common. Infected animals can become asymptomatic carriers (Nicholson *et al*, 2000).

7.1.3.4 Outbreaks associated with the causal agent and waste products

One outbreak of Salmonella caused by the consumption of bean sprouts in England, was traced back to contaminated mung bean seed produced in Australia. In this instance, the mung bean seed was contaminated with aerially transported meat meal from an adjacent livestock feed processing plant (*pers comm*. Slatter, 2001). As a consequence of the outbreak, Australia lost this export market.

Of the 14 examples of outbreaks of human foodborne disease in the US researched by Nguyen-the & Carlin (1994), three cases involving *Listeria monocytogenes*, Salmonella and *Vibrio cholerae* could be traced back to the use of organic fertilisers or polluted irrigation water.

An outbreak of *S. bovismorbificans* was isolated by Queensland Health between May and July 2001, with the most likely link being iceberg lettuce. A total of four farms which supplied lettuces at time of outbreak were audited. None of the farms were using organic fertilisers or waste compost at the time of the problem. All of the farms used synthetic fertilisers only. One of the farms was irrigating with untreated river water. Another farm had started to trial vermitec (worm castings) in a small section of the farm, some distance from the lettuces. Further investigations are continuing (*pers comm.* Stafford, 2001).

Organically produced sprouts and lettuce in the US have also been associated with Salmonella outbreaks. Profiles of organic and conventional produce found salmonella in 7.7% and 0% of sprout samples respectively.

In terms of animal health outbreaks, Vanselow & Hornitzky (2001) documented a case of *S. Typhimurium* on a NSW dairy property. An outbreak in 2000 occurred after cattle had grazed a paddock irrigated with liquid effluent. The effluent pond, manure heap and solids trap were all found to be contaminated with *S. Typhimurium*. A 1999 outbreak had occurred on the same property after manure had been ploughed into a paddock.

In cattle at pasture, infected drinking water in stagnant ponds is a significant source of infection and may be contaminated by carrion-eating birds.

7.1.3.5 Survival of the causal agent in feedlot waste products

Several studies on survival of Salmonella in waste products have been undertaken, although none from Australia in terms of bovine waste products. The Eamens et al (2001) study conducted research for Sydney Water on the survival and growth of pathogenic bacteria after agricultural application of human waste included Salmonella and this will be reported here.

As for *E.coli* the first study found that agricultural land which received lagooned biosolids was likely to reach baseline levels for Salmonella in 4-5 months. Those that received dewatered biosolids took at least a further 1-2 months to reach the same level.

In the second study (Eamens, unpublished), survival of Salmonella was also determined to be prolonged. Detectable levels were still being found in one plot at 68 weeks.

Summaries of overseas research include:

- Animals experimentally allowed to graze pasture spread with slurry are not easily infected. The danger of disseminating salmonellosis by the use of a slurry system can be significantly reduced if the slurry is stored for at least one month before spreading and if the pasture treated with stored slurry is not grazed for a similar period after spreading (Jones, 1980).

- In a Finnish experiment, aeration of cattle slurry (either in the laboratory or on the farm) resulted in a major reduction in Salmonella levels (Heinonen-Tanski *et al*, 1998). The four on-farm experiments, which typically involved aeration of 600-850 m^3 tanks over a 10 to 35 day period, resulted in a reduction of between 2-4 fold (Heinonen-Tanski *et al*, 1998). The aeration of the farm tanks was associated with a rise in tank temperature – in some cases 40°C above the ambient temperature of 0°C (Heinonen-Tanski *et al*, 1998).

- In a series of experiments in which bovine manure or bovine slurry was spiked with *S. typhimurium* and then held at 4°C, 20°C and 37°C, workers in the USA calculated the time for a 90% reduction – termed the decimal reduction time (Himathongkham *et al*, 1999). The key findings of this study are shown in Table 5.

- The data generated by Himathongkham *et al* (1999) can be used in a risk assessment approach for setting guidelines eg if it is decided that a $\geq 10^5$ reduction in *S. typhimurium* is needed, then manure should be held at 102 days at 4°C or 42 days at 37°C (very similar figures to those reported for *E. coli* O157 in Table 3). The study of Himathongkham *et al* (1999) was a laboratory-based study which may limit application of the data to field situations.

TABLE 5: *S. TYPHIMURIUM* DESTRUCTION RATE IN CATTLE MANURES STORED AT DIFFERENT TEMPERATURES

Storage temp. (°C)	Manure type	Manure heap location	Decimal reduction time* (d)
4	Manure	Top	12.70
4	Manure	Mean (middle and bottom)	20.33
4	Slurry	ND	16.42
20	Manure	Top	24.69
20	Manure	Mean (middle and bottom)	9.36
20	Slurry	ND	12.69
37	Manure	Top	8.36
37	Manure	Mean (middle and bottom)	1.73
37	Slurry	ND	2.37

*Time required to achieve a 1 log reduction in pathogen numbers

ND = not determined

- Although Salmonella may be found in low numbers (less than 100 cfu/g) in slurries, 90% die during the first 2-4 weeks of storage. Furthermore, they only survive on grass for short periods following spraying (Jones, 1980) but may remain in soil for prolonged periods of up to 300 days in the UK (Jones, 1986).

- Other UK-based studies in the 1970s and 1980s showed that Salmonella could survive from 11 to 41 weeks in cattle slurry depending upon a number of factors including Salmonella type, the slurry composition and the time of year (Nicholson *et al*, 2000).

- Salmonella has been shown to survive in soil for prolonged periods, up to 300 days in UK soils that have been spread with cattle slurry (Jones, 1986).

- In a bench-scale composting system, *S. Enteritidis* that had been seeded at a level of 7 log cfu/g of raw compost feed was not detected after 48 hours at 45°C. There was no change in bacterial numbers when the composting system was held at room temperature (Lung *et al*, 2001).

7.1.4 *Coxiella burnetii*

7.1.4.1 Background levels in bovine waste

Serological studies have reported a low to very low prevalence of antibodies to *C. burnetii* in Victorian dairy cattle (Hore & Kovesdy, 1972) and South Australian beef cattle (Durham & Paine, 1997). Levels in waste are not known.

7.1.4.2 Infectious Dose

An infectious dose amount was not found in the reviewed literature.

7.1.4.3 The disease in humans and cattle

C. burnetti is a bacterium that causes Q fever (Norlander, 2000). Human infection can be sub-clinical, acute or chronic in form. Asymptomatic disease is the most common form (Norlander, 2000) where most people who test positive are not aware they have had Q fever in the past. Where affected, a wide range of severity of illness exists. The chronic form of Q fever is typically characterised by endocarditis while the acute form is typically an influenza like condition (Norlander, 2000).

It should be noted that epidemiological studies indicate that Q fever in humans in Australia is primarily a disease of adult males that occurs in eastern Australia, particularly southern Queensland and northern New South Wales (Garner *et al*, 1997). Hence, the relatively low serological prevalence reported for Victorian and South Australian cattle in 6.1.4.1 should not be extrapolated to other regions where the incidence of human Q fever is higher.

Cattle, unlike humans, do not develop any clinical illness as a result of infection with *C. burnetii* (Norlander, 2000). Pregnant cattle are more likely to harbour the bacterium causing Q fever.

7.1.4.4 Outbreaks associated with the causal agent and waste products

Outbreaks of Q fever are quite common amongst abattoir workers and people in contact with cattle. Vaccination programs are readily available.

C. burnetii is carried by cattle, sheep and goats and is transmitted by contact with animal faeces, urine or by inhaling dust from infected premises.

Epidemiological studies in Europe have implicated exposure to bovine manure as a possible risk factor for Q fever (Jorm *et al*, 1990; Reintjes *et al*, 2000).

7.1.4.5 Survival of the causal agent in feedlot waste products

No information of survival of *C. burnetti* in waste products was found.

7.1.5 Leptospira spp

7.1.5.1 Background levels in bovine waste

Leptospira spp are aerobic spirochaetal bacteria (Plank & Dean, 2000). Early serological studies indicate that the serovars hardjo, pomona and tarassovi are most common in Australian cattle (Keast *et al*, 1964; Spradbrow, 1964). More recent surveys in North and Central Queensland (Norton *et al*, 1989; Black *et al*, 2001) and Victoria (Milner *et al*, 1980) have shown that the serovar pomona was not common.

7.1.5.2 Infective dose range

1000 organisms was cited in the literature as causing an infectious dose.

7.1.5.3 The disease in humans and cattle

Leptospirosis is a zoonotic disease. In humans, Leptospira spp infections are associated with fever, mylagia, headache and jaundice (Plank & Dean, 2000). About 90% of cases are mild and self-limited (Plank & Dean, 2000). Weil's syndrome in humans is a serious form of the infection in which there is hepatic and renal impairment, haemorrhage and vascular collapse – a condition that can be rapidly fatal (Plank & Dean, 2000). There were 236 cases of leptospirosis in Australia in 2000 (*pers comm.* Communicable Diseases Network Australia, 2000).

Some animals carrying Leptospira may not appear to be sick.

7.1.5.4 Outbreaks associated with the causal agent and waste products

In early December 1998, the Northern Rivers Public Health Unit (north-eastern New South Wales) was alerted to a cluster of eight leptospirosis cases. All cases were employees of a local meat works. Leptospira serovars isolated included pomona and hardjo. Symptoms included headache, fever, muscle pain, sore eyes, abdominal pain, vomiting, jaundice, and rash. Five of the eight cases were hospitalised. The infection could not be traced to any particular source. Unfortunately, records of stock killed during the exposure periods were not available. All cases reported exposure to large volumes of animal urine during the course of their work. Protective clothing provided included an apron, gloves, and rubber boots. (Smythe *et al*, 1999)

Humans usually become infected through contact with urine contaminated soil and water, with infected animal tissue or from rat bites (Plank & Dean, 2000). The spread of leptospirosis occurs under wet conditions, from bacteria that are shed in the urine of infected cattle (Corney, 2001). Transport and dissemination of Leptospira may therefore occur quite rapidly in waste products from feedlots.

7.1.5.5 Survival of the causal agent in feedlot waste products

Leptospira spp are unable to multiply in the environment – being capable of reproduction only with animal hosts (Plank & Dean, 2000). This is balanced by the fact that Leptospira can survive well in soils and water. As an example, in New Zealand, Leptospira serovar pomona has been shown to survive in soil for up to 42 days (Hore & Kovesdy, 1972).

Humans usually become infected through contact with urine contaminated soil and water, with infected animal tissue or from rat bites (Plank & Dean, 2000).

The spread of leptospirosis occurs under wet conditions, from bacteria that are shed in the urine of infected cattle (Corney, 2001).

It is therefore concluded that transport and dissemination of Leptospira may therefore occur quite readily in waste products from feedlots.

7.1.6 Listeria

7.1.6.1 Background levels in bovine waste

Vanselow & Hornitzky, 2001 did not find Listeria in the faeces of Australian cattle. They suggested that a lower prevalence of Listeria than reported overseas may be due to a lower usage of silage.

European based studies have reported that the faecal excretion rate in cattle of *L. monocytogenes* can vary from a few percent to over 50% (Skovgaard & Norrung, 1989). In the USA, the prevalence of *L. monocytogenes* in beef cattle in Nebraska varied from 0 - 4% (Siragusa *et al*, 1993). The feeding of a high proportion of silage or silage of a poor quality have been suggested as the cause of a high prevalence of *L. monocytogenes* in faecal excretion of cattle (Fenlon, 1986).

7.1.6.2 Infective dose range

100-1000 organisms depending on the source.

7.1.6.3 The disease in humans and cattle

In non-pregnant humans, *L. monocytogenes* causes meningitis, encephalitis or septicaemia (Swaminathan *et al*, 1995). While the number of reported cases is low, the disease is important as around 25% of cases result in severe neurological trauma and or death (Swaminathan *et al*, 1995). In pregnant women, *L. monocytogenes* can cause a flu-like septicaemia that can result in an infected foetus leading to abortion, stillbirth or premature birth (Swaminathan *et al*, 1995).

Listeriosis in cattle is also characterised by abortion, perinatal death, meningoencephalitis or septicemia.

7.1.6.4 Outbreaks associated with the causal agent and waste products

An outbreak in 1981 in Nova Scotia resulted in 41 cases of listeriosis including 18 deaths. The outbreak was traced to *L. monocytogenes* on coleslaw that had been made from cabbage grown in a field fertilised with manure from Listeria-infected sheep.

One of the examples of outbreaks of foodborne disease researched by Nguyen-the and Carlin (1994), attributed a case to *L. monocytogenes*, through the use of organic fertilisers or polluted irrigation water.

7.1.6.5 Survival of the causal agent in feedlot waste products

Current research being undertaken in the US (USDA ARS, 2000) is investigating the survival of listeria in manure piles during winter and summer. Detailed results are not as yet publicly available.

Other research has identified that *L. monocytogenes* can last in soil for some time. Salmonella and *L. monocytogenes* could survive for months in sewage sludge applied to agricultural soils (Brackett, 1999).

Like other pathogens, the decline in viable numbers of *L. monocytogenes* in beef cattle slurry is temperature dependent (declining more rapidly at 17°C than 4°C). (Kearney *et al*, 1993).

In addition, Listeria species are widely distributed in the rhizosphere (the thin layer of soil that sticks to the roots of plants) and there is evidence that the natural incidence is higher in soils that have not been disturbed for long periods of time (Dowe et al, 1997).

7.1.7 Yersinia

7.1.7.1 Background levels in bovine waste

There are 11 species of Yersinia (Gray, 1995), however only two species are relevant to bovine manure and public health issues, *Y. enterocolitica* and *Y. pseudotuberculosis.*

Both Australian (Slee *et al*, 1988) and overseas studies (Busato *et al*, 1999) have suggested that *Yersinia* spp should be regarded as being normally present in the bovine intestinal tract. However, Vanselow & Hornitzky (2000) did not find Yersinia in feedlot cattle nor in any other beef, dairy or sheep samples.

7.1.7.2 Infective dose range

A review of the literature did not identify the infectious dose of Yersinia.

7.1.7.3 The disease in humans and cattle

Enterocolitis and enteritis in Australian cattle have been associated with infection due to *Y. pseudotuberculosis* (Callinan *et al*, 1988; Slee *et al*, 1988).

The most common diseases caused by Yersinia in humans are haemorrhagic enterocolitis and terminal ileitis septicaemia (Gray, 1995). There is a relatively low prevalence of human infections with Yersinia in Australia, mostly attributed to *Y. enterocolitica*.

Y. enterocolitica can cause gastroenteritis mainly in young children, with the most common symptoms being fever, abdominal pain and diarrhoea. In older children the bacteria can cause mesenteric adenitis (pseudoappendicitis). Arthritis and erythemia nosodium have been known to occur in adults (Food Safety Information Council, 2001).

7.1.7.4 Outbreaks associated with the causal agent and waste products

Most of the serotypes isolated from bovine faeces are not normally pathogenic to humans (Prpic and Hughes 1989). No outbreaks associated with bovine waste were found in this literature review.

7.1.7.5 Survival of the causal agent in feedlot waste products

A review of the literature did not find any studies associated with the survival of the agent in feedlot waste.

7.1.8 *Clostridium* spp.

7.1.8.1 Background levels in bovine waste

Both *Cl. perfringens* and *Cl. botulinum* are widely distributed in the general environment, including environments where cattle are raised (Onderdonk & Allen, 1995). Actual levels in Australia are unknown.

Animal Health Australia reports that for the year 2001, botulism in cattle has a low sporadic occurrence.

7.1.8.2 Infective dose range

A quite high infectious dose is required, from 10^6 - 10^{10} organisms.

7.1.8.3 The disease in humans and cattle

Cl. perfringens can cause gas gangrene as well as food poisoning in humans (Onderdonk & Allen, 1995). *Cl. botulinum* is usually associated with low acid foods. Botulism in cattle is a serious disease problem, and is a significant cause of stock losses in the northern beef industry (De Witte, 1996).

7.1.8.4 Outbreaks associated with the causal agent and waste products

In the past, chicken litter was used in Queensland as a feed supplement for cattle in order to provide high protein levels. A loss of over 5000 head of feedlot cattle occurred when one batch of chicken litter proved to be contaminated with the toxin from *Cl. botulinum* (Douglas, 2001).

There is no strong linkage of human infections to cattle products or cattle waste products. Pathogens such as *Cl botulinum* are naturally present in some soil, and are often present on fresh produce.

Both *Cl. perfringens* and *Cl. botulinum* are widely distributed in the general environment, including environments where cattle are raised (Onderdonk & Allen, 1995).

Outbreaks of *Cl. botulinum* have occurred on farm. In one documented case overseas the cycle was initiated by feeding brewers' grains contaminated with proteolytic *Cl. botulinum* type B to the cows. Spreading of manure containing faeces of these cows increased the contamination of the pastures. In grass silages prepared with wilted grass from these pastures, the number of *Cl. botulinum* increased and toxin was produced. Feeding cows with the contaminated silage fodder completed the cycle. (Notermans *et al*, 1981)

7.1.8.5 Survival of the causal agent in feedlot waste products

Clostridium spp are spore forming organisms with a capacity to survive for prolonged periods in the environment (Onderdonk & Allen, 1995).

Heat resistance is an important issue with *Cl. botulinum*. Vegetative cells are killed by 5 mins temperature exposure at 60°C, the toxin is inactivated by 5 mins at 85°C and the spores by 10 mins at 110-112°C (this is a rough guide only as kill rate is influenced by pH, initial numbers and other factors).

In the Eamens (2001) study on Australian human waste *Cl. Perfingens* survival time on agricultural land may be in excess of 7 months under favourable environmental conditions. It was noted that rises in the bacterial spore concentrations were associated with warm, wet conditions.

7.1.9 Mycobacterium

7.1.9.1 Background levels in bovine waste

An emerging issue in food safety is *Mycobacterium avium* subspecies paratuberculosis (MAP) referred to as Johne's disease in cattle. It has been reported in about 2000 cattle herds in Victoria, Tasmania, New South Wales and South Australia (Animal Health Australia, 2001).

Mycobacterium bovis (bovine tuberculosis) has not been considered given Australia's declared freedom from bovine tuberculosis on 31 December 1997. The nature of the disease has caused occasional cases. For example, in 2001 five properties were affected, the source of which was traced to a single property.

7.1.9.2 The disease in humans and cattle

MAP is the organism responsible for Johne's disease of cattle and a wider range of animals (eg sheep, goats, alpaca). Johne's disease is a chronic inflammation of the intestine in animals (Safefood NSW, 2001). The main symptom in cattle is diarrhoea and wasting (Animal Health Australia 2001). Animals usually become infected when young and can carry the organism in their gut walls for many years without showing clinical signs of infection (Animal Health Australia, 2001). In Australia, there are control programs to limit the spread of Johne's disease in cattle as well as sheep (Whittington *et al*, 2001).

Crohn's disease is a chronic inflammatory bowel disease in humans. Due to the similarity of the diseases there has been speculation that the MAP bacterium responsible for Johne's disease may also be linked to Crohn's disease. This link has yet to be established and there is a lack of reliable data on the incidence and prevalence of both diseases.

The European Commission Report March 2000 (Scientific Committee on Animal Health and Animal Welfare) is considered the most definitive report on MAP and the Report's conclusion states: "… the currently available evidence is insufficient to confirm or disprove that MAP is a causative agent of at least some cases of Crohn's disease in man. There are sufficient grounds for concern to warrant increased and urgent research activity to resolve the issue."

The UK Advisory Committee on the Microbiological Safety of Food concludes "…whilst studies continue to be carried out in an attempt to resolve the issue, there appears to be a general view that this is not a controversy that will be resolved in the near future, if at all." (Safefood NSW, 2001).

7.1.9.3 Outbreaks associated with the causal agent and waste products

The first Johne's disease case in cattle was diagnosed in 1919 in Victoria. It is now endemic in most states of Australia except Queensland, the Northern Territory and Western Australia (Animal Health Australia, 2001).

There have been no known outbreaks of Crohn's disease associated with cattle waste.

MAP grows in the gut tissue of affected animals and is shed in the faeces of infected animals. Infection can occur through the ingestion of infected faeces from contaminated pasture or water (Animal Health Australia, 2001).

7.1.9.4 Survival of the causal agent in feedlot waste products

The bacterium is reasonably stable in the environment and may survive 12 months or more in moist and sheltered situations (Animal Health Australia, 2001).

7.1.10 Mycotoxins

7.1.10.1 Background levels in bovine waste

Mycotoxins are poisons produced by moulds (microscopic fungi) growing in feedstuffs. Five mycotoxins or groups of mycotoxins are considered to be important in human health - aflatoxins, ochratoxin A, fumonisins, trichothecenes and zearalenone (Pitt & Tomaska 2002). Background levels of aflatoxins in peanuts are well documented but not for other food stuffs. Pitt & Tomaska (2001) assume that other foods do not contribute substantially to aflatoxin exposure in Australia. The actual levels in bovine waste are unknown and may not be related to levels in beef.

7.1.10.2 The effect on humans and cattle

Mycotoxins are common in stock feed, but their effects on animal productivity are limited because of the low concentration of the toxicant and the relative tolerance of

animals to the toxin (Blaney & Williams 1991). Cattle are considered more tolerant of these toxicants than pigs or poultry.

Symptoms of mycotoxin poisoning in Australian cattle include bovine hyperthermia, lupinosis, facial eczema, ergotism, diplodiosis, and paspalum staggers (Bryden, 1989).

More recently feed producers have been concerned with sorghum grain infected with ergot, inducing alkaloid poisoning in livestock (Blaney *et al*, 2000). Cattle tolerate up to 2 ppm of the ergot alkaloid in the feed ration. Since October 1997 trading regulations have been introduced to ban the use of feed sorghum infected with more than 0.3% of ergot by weight (Ryley & Blaney, 2001).

In humans, mycotoxins are suspected carcinogens and have also been associated with endocrine disruptors (see section 6.3.3).

7.1.10.3 Outbreaks associated with the causal agent and waste products

Unknown.

7.1.10.4 Exposure (transport and dissemination)

Moulds such as ergot (Claviceps species) can grow on grain and produce mycotoxins before harvest. Other moulds infect grain before harvest but produce most mycotoxins during storage. The moulds that produce mycotoxins are not always visible, but feed stuffs that become visibly mouldy during storage when fed to livestock are very likely to result in reduced productivity.

The fungi that produce aflatoxins (*Aspergillus flavus* and *A parasiticus*) most commonly grow during storage of summer crops (maize, peanuts and sorghum) but wheat and barley can also be affected (Blany, 2001).

In general fungi require warm, moist conditions to prosper but each require their own special environmental conditions to grow. Fungal growth is likely to occur suddenly and dramatically when their critical needs are met although it is not possible to detect this through casual observation.

It is not known whether cattle that feed on grains containing mycotoxins will produce levels in their faeces or urine that could subsequently be taken up by food crops or other animals. It is unlikely that mycotoxins in cattle feed would still be at sufficient levels in manure (after adsorption and degradation processes through the intestinal tract of the cattle) to pose a reasonable risk.

7.1.10.5 Survival of the causal agent in feedlot waste products

Unknown - there is no knowledge of passage of mycotoxins through to waste material and the subsequent degradation process in the environment.

7.1.11 Other - Brucellosis, Anthrax, Shigella, *Vibrio Cholerae* and Legionella

Bovine brucellosis is a highly contagious disease caused by *Brucella abortus*. During 2000, 24 cases of human brucellosis were reported (Communicable Diseases Network, 2000). Bovine brucellosis however has not been considered in detail in this report due to Australia's declaration of freedom from bovine brucellosis in 1989 (Animal Health Australia, 2001).

There does not appear to be any definitive link between faecal waste matter and contraction of Anthrax in either humans or animals. Transmission is more likely to occur via contact with decomposing carcases. The concern with Anthrax however, is that it persists in soil for many years, particularly in warm climates and in soils with a neutral to alkaline pH that contain organic matter (Animal Health Australia 2001).

Shigella and *Vibrio Cholerae* are two pathogens found overseas in waste. However, in recent times in Australia they have not been found in animal waste or food products produced in Australia (only in imported produce).

Legionella pneumonia is a bacteria often associated with potting mixes and soils in humans. It is commonly found in waterways and soil but no definite link to cattle waste has been established.

7.2 PARASITIC PROTOZOA

7.2.1 Cryptosporidium

7.2.1.1 Background levels in bovine waste

Two species of Cryptosporidium are found in cattle, *C. parvum* and *C. muris* (recently renamed as *C. andersoni*) with only *C. parvum* being capable of also infecting humans (Fayer, 1997).

There is now an emerging consensus that there are two transmission cycles in humans – human only and human-cattle (Peng *et al*, 1997). Recent genetic studies have shown that there are two main genotypes of *C. parvum* termed genotypes 1 and 2 (Peng *et al*, 1997). Genotype 1 has been found only in human isolates while genotype 2 has been found in both calf isolates and humans who had direct exposure to infected cattle or who consumed items contaminated with cattle faeces (Peng *et al*, 1997).

The prevalence of infection with *C. parvum* can be very high. In the US, 50% of two week-old calves and 22.4% of all calves (1 to 17 weeks) were positive (Garber *et al*, 1994). As a result of this prevalence level, Garber *et al*, (1994) concluded that virtually all herds above 100 cows would be positive. The lower prevalence level reported by Wade *et al*, (2000) is presumably due to the smaller herd size in this study as compared with that of the Garber *et al*, (1994) study.

A US based study of beef herds has shown that reproductive management that results in a shorter calving season and the use of a lower stocking rate may both be associated with a reduction in the risk of the shedding of *C. parvum* oocysts (Atwill *et al*, 1999).

No Australian based studies on the issues such as the prevalence and level of excretion of *C. parvum* in Australian cattle were found.

7.2.1.2 Infective dose range

The infectious dose ranges from 10-100 cysts.

7.2.1.3 The disease in humans and cattle

C. parvum has been associated with the re-use of human waste as well as exposure of humans to cattle, sheep and pig waste. Watery diarrhoea and fever are the typical signs of human infections with *C. parvum* (Current & Garcia, 1991). The disease is usually self-limiting and causes little long term damage to the healthy individual (Current & Garcia, 1991).

While sheep, horses and pigs are susceptible to *C. parvum* infection, dairy and beef calves are particularly susceptible (Kuczynska & Shelton, 1999). An infected calf has been estimated to produce 30 billion oocysts over a 1-2 week period (Kuczynska & Shelton, 1999). There is a dispute in the literature on whether adult cows excrete oocysts. Some studies have found that only calves of less than 30 days of age excrete oocysts eg. Wade *et al*, (2000). In contrast, Scott *et al*, (1994) have reported that apparently healthy adult cows can have up to 18,000 oocysts per g of faeces. There has been a suggestion that the reports of oocysts in faeces of adult cows are due to mis-identification of *C. muris* as *C. parvum* (Wade *et al*, 2000).

7.2.1.4 Outbreaks associated with the causal agent and waste products

In 1993 over 400,000 people in Milwaukee, WI were infected with *C. parvum* from contaminated drinking water. Heavy rains, cattle manure on fields, abattoir waste and sewage overflow were considered potential sources. However, after oocysts from four affected persons failed to infect animals and were identified genetically to be of human origin, the probable source was human sewage overflow (Fayer, 2000).

An outbreak following the consumption of apple cider was associated with zoonotic transmission. Fresh pressed cider was squeezed from apples collected from an orchard on which an infected calf grazed. Some apples had fallen onto the ground and had probably been contaminated with infectious oocysts (Slifko *et al*, 2000).

In Australia, the best known outbreak of Cryptosporidium (and Giardia) was the Sydney water outbreak in July - September 1998. In the final inquiry report, attempts were made to determine whether the Cryptosporidium oocysts recovered from water were of human or animal origin. The oocysts were sent to laboratories in Australia

and the UK for DNA typing, which could have indicated whether oocysts were of Genotype 1 (transmissible only between humans) or Genotype 2 (transmissible between cattle and humans). However the tests were unsuccessful, possibly because many of the oocysts were degraded and may not have contained DNA (Health Stream, 1998). Reports that manure and agricultural runoff from heavy rains were responsible for one of the Sydney outbreaks have not been substantiated.

7.2.1.5 Exposure routes (transport and dissemination)

The oocyst is the stage transmitted from an infected host to a susceptible host by the faecal-oral route. Routes of transmission can be (1) person-to-person through direct or indirect contact (2) animal-to-animal, (3) animal-to-human, (4) water-borne through drinking water or recreational water, (5) food-borne, and (6) possibly airborne (Fayer, 2000).

7.2.1.6 Survival of the causal agent in feedlot waste products

Cryptosporidium oocysts can stay viable in faeces for prolonged periods. A USA study found that 1 log reduction in viability of oocysts in calf faeces required 400 days of storage at 4°C (Jenkins *et al*, 1997). A Canadian study reported a shorter survival period – with oocysts being non-viable and non-infective after storage in cattle faeces for either 8 weeks (4°C) or 4 weeks 25°C (Olson *et al*, 1999). IFST (1999) reported oocysts can remain viable for about 18 months in a cool, damp or wet environment and are quite common in rivers and lakes, particularly where there has been sewage or animal contamination.

The Canadian study on oocyst survival in cattle faeces found the same survival period in normal soil ie no viable or infective oocysts were detected after 8 weeks at 4°C or 4 weeks at 25°C (Olson *et al*, 1999). A longer survival period was found when autoclaved soil was used 12 weeks at 4°C or 6 weeks at 25°C (Olson *et al*, 1999).

7.2.1.7 Potential Threat

Cryptosporidium is an important agent in waste application given its history in outbreaks, its apparent prevalence and survival in faeces.

7.2.2 Giardia

7.2.2.1 Background levels in bovine waste

There are three morphologically distinct species of Giardia – *G. duodenalis*, the form of Giardia occurring in most mammals, including humans and cattle; *G. agilis* occurring in amphibians and *G. muris* in rodents (Thompson *et al*, 2000). There is a tendency for North American literature to use the term *G. lamblia* to describe the form of Giardia associated with humans however *G. lamblia* has no formal standing and will not be used in this review.

Molecular studies have shown that there is wide diversity within *G. duodenalis*. The

current understanding is that there are two major genotypes, which are given different names in different areas of the world. In Australia, these two major genotypes are termed Assemblage A and Assemblage B (Thompson *et al*, 2000). Assemblage A consists of two further sub-divisions – A-I and A-II. The A-I sub-division consists of closely related isolates that are found in both humans and animals, including cattle. The A-II sub-division consists entirely of human isolates. The Assemblage B genotype consists mainly of human isolates – although there are some animal isolates. There are other genotypes within the species *G. duodenalis* – in particular a subgroup solely associated with livestock (Ey *et al*, 1997). A brief summary of the classification and host association of the species *G. duodenalis* is as follows:-

Genotype	Sub-division	Host
Assemblage A	A-I	Humans, livestock, cats, dogs
Assemblage A	A-II	Humans
Assemblage B		Humans, dogs, rats, beavers
Livestock*		Cattle, goats, pigs

*This genotype is solely associated with livestock and does not affect humans

There is a relatively high prevalence of Giardia in neonates and young calves (Xiao and Herd, 1994). In both the US and Canada, it was found that 100% of calves are infected at some stage in the first 20 weeks of life (Ey *et al*, 1997; Thompson *et al*, 2000). In New York state, the mean number of Giardia cysts in 263 faecal samples was 21,090 oocysts/g faeces (Wade *et al.*, 2000).

No information on the prevalence or level of oocyst excretion in Australian cattle was found.

7.2.2.2 Infective dose range

A review of the literature found a wide variance in infectious doses from 1 - 200 oocysts.

7.2.2.3 The disease in humans and cattle

There is a belief that the zoonotic transmission of *G duodenalis* is most strongly associated with Assemblage A, sub-division A-I genotype (Thompson *et al*, 2000).

G duodenalis is the most common gastro-intestinal protozoan parasite detected in humans world-wide and is the aetiological agent of the diarrhoeal disease giardiasis (Thompson *et al*, 2000).

Giardia in humans can result in illness ranging from mild to chronic.

7.2.2.4 Outbreaks associated with the causal agent and waste products

Unknown (also refer to the Sydney water outbreak described in 6.2.1.4).

7.2.2.5 Exposure routes (transport and dissemination)

As for Cryptosporidium 6.2.1.5

7.2.2.6 Survival of the causal agent in feedlot waste products

In a US study, researchers took rectal samples and environmental samples to determine the prevalence of *G duodenalis* in cattle. Positive results for rectal samples were 6.5% versus ground faecal samples at 4.7%. While there is some inactivation of pathogens in faeces after cattle have defecated, evaluation of ground faecal samples may accurately reflect the prevalence of *G duodenalis*. (Hoar 1999).

7.2.2.7 Potential Threat

The fact that the genotype of *G. duodenalis* present in cattle has the potential for zoonotic transmission means that this organism is of importance in manure re-use applications.

7.3 VIRUSES

Replication of viral pathogens outside their usual host is rare, and thus viral pathogens in animal wastes are unlikely to pose a significant health risk to humans (Nicholson et al, 2000). The exception to this may be the rotaviruses which are the causative agent of scour in calves. The exact relationship between animal and human rotaviruses remains unclear as does the ability of animal rotaviruses to cause disease in humans.

7.4 CHEMICAL CONTAMINANTS

7.4.1 Heavy Metals

7.4.1.1 Background levels in bovine waste

Feedlot wastes consist of water, excreta and spilt feed with analyses reporting no significant levels of heavy metals (Watts, 1992). Heavy metals are usually present in feedlot manure in some way because of the addition of mineral supplementations and trace minerals to the feed.

We can only speculate that manure will contain heavy metals which have been found in offal items under the National Residue Survey. These include (in order of number of samples containing residues) copper (Cu), zinc (Zn), selenium (Se), cadmium (Cd), arsenic (As), mercury (Hg) and lead (Pb). Most grain crops also contain some heavy metals (AFFA, 2000).

Cd, chromium (Cr), As, Pb, Hg and nickel (Ni) are the focus of heavy metal contaminants in both manures and rock fertilisers due to their potential for uptake and concentration in harvested crops (McLoughlin *et al*, 2000; Sloan *et al*, 1997).

In the UK, the highest metal concentrations in home-mixed and mill-mixed beef cattle feeds were 190 mg/kg for Zn (dry weight basis), and 35 mg/kg for Cu (Nicholson *et al*, 1999). Most of the metals were in the formulated cake or pellets, which were very similar in composition to the feeds formulated for dairy cows. Concentrations of Ni, Pb, Cd, As and Cr in all cattle feedstuffs except the mineral supplements, were at concentrations of less than 5 mg/kg. Beef cattle feeds had the lowest concentrations of heavy metals of all the feeds tested.

7.4.1.2 The effect on humans and cattle

A range of health effects, both acute and chronic are associated with heavy metals. Queensland Health (2000) summarised the effects of metals on health as follows (modified to address only feedlot manure heavy metals)

- As - Health impact depends upon the type of As but both chronic and acute symptoms may arise. Implicated in the production of skin and lung cancers.

- Cd - Both acute and chronic symptoms can occur with kidney, lungs and bones affected. With chronic Cd poisoning, there may be a lag between exposure and onset of symptoms.

- Cr - Both acute and chronic effects are observed, with Cr (VI) being the toxic type, although Cr can also cause skin damage.

- Cu - Is not particularly toxic to humans or animals and acute effects are rarely observed.

- Pb - Effect can depend on a number of factors including type of Pb and age of the subject. In it's most chronic form, lead poisoning can have an effect on blood, kidneys, peripheral and nervous systems. Exposure in infants is serious.

- Hg - Can have acute effects on the lungs and chronic effects on the central nervous system.

- Ni - Acute toxicity effects are fairly rare but chronic effects include allergy and cancer.

- Se - Both acute and chronic toxicity occurs (most pertain to absorption from the atmosphere)

- Zn - Most reports pertain to acute toxicity including vomiting, muscle pains and fever.

7.4.1.3 Outbreaks associated with the causal agent and waste products

Unknown

7.4.1.4 Survival of the causal agent in feedlot waste products

Depending on the purity of the salts used in the feed ration, manure is a potential source of heavy metal contamination (Xue *et al*, 2000).

The feeding of mineral supplements to lot-fed cattle is largely in the form of inorganic salts such as limestone, muriate of potash, bentonite, or phosphates (Sneath & Wood 2001). Trace minerals such as magnesium, chlorine, Cu, iron, cobalt, Se, iodine, Zn and manganese are usually administered as a commercially prepared formulation added at about 0.1% by weight of the ration. Bore water supplied to the cattle may be another source of dissolved minerals including sodium. Nutrients in excess to cattle requirements are excreted in the faeces.

Concern has been expressed about the repeated use of cattle manure as a fertiliser for growing crops. Applications of phosphatic fertilisers to crops are recognised as a source of the contaminant Cd (Hamon *et al*, 1998).

Repeated use of manure or compost for food crop production will only lead to the bioaccumulation of heavy metals in food plants if the:-

- Rate of application to a specific soil type and crop type results in excessive bioaccumulation in the edible portion of the crop.
- Concentration of a given heavy metal is high in the fresh manure (could be from a source of inorganic phosphate (P) in which Cd contamination is excessive – or supplemental levels of Cu in the feed ration is above dietary requirements of the animal).

In many Australian agricultural soils Zn and less commonly Cu are limiting (ie deficient) for crop growth. Provided that application rates consider a mass balance approach for inorganic ions known to be close to the upper limit of crop and soil requirements, the repeated application of composts and manures for crop production does not pose a risk.

In Australia upper limits of 300 mg Cd, 500 mg of Pb and 5 mg of Hg per kg of inorganic phosphate product apply. However typically inorganic phosphate fertiliser is applied at a rate of 20 kg P/ha, whereas manure application may vary from 1 to 20 tonnes/ha dry matter (dm). In the NSW Biosolids code, maximum limits of 3 mg/kg Cd, 150 mg/kg Pb and 1 mg/kg Hg are specified for "Grade A" (applied to agricultural soils), with limits of 200 mg/kg and 100 mg/kg for Zn and Cu respectively (McLoughlin *et al*, 2000).

Within European agricultural catchments, the repeated application of animal manures or slurries to land has been responsible for increases in soil concentrations of Cu and Zn (Xue *et al*, 2000). With respect to bio-accumulation in crop plants, the risk of Cu and Zn poisoning in human consumers is lower relative to Cd (McLoughlin *et al*,

2000, Moolenaar *et al*, 1997b). However both these compounds are toxic at relatively low concentrations to microorganisms in the soil (McGrath *et al*, 1995). Indeed the toxic properties of these metals have been used in horticulture to control outbreaks of plant diseases. As a result, the background levels of some heavy metal compounds in some Australian horticultural soils may already be very high (Merrington, 2001) even in the absence of the application of animal manures.

7.4.2 Chemical pesticides

Chemical pesticides such as organochlorines, organophosphates and synthetic pyrethroids have been considered within this study but dismissed as a significant causal agent given the low prevalence in samples taken under the National Residue Program.

7.4.3 Hormones and Endocrine Disruptors

There is a growing public concern about the possible impact of endocrine disruptors (substances that interfere with the human endocrine system) on human health. Possible adverse impacts have included increased incidence of testicular cancer (Adami *et al*, 1994), prostrate and breast cancer and malformations of the external and internal male genitalia (Kledal *et al*, 2000).

While a range of chemicals could function as endocrine disruptors, those compounds that interfere with the oestrogen, androgen and thyroid signalling systems are the major ones that have been considered to date (Kledal *et al*, 2000). Environmental oestrogenic compounds (ie endocrine disruptors) include phyto- and myco-oestrogens which are found in many plants and fungi (Toppari *et al*, 1996).

The synthetic hormones used for growth promotion in cattle are oestrogenic compounds and could function as endocrine disruptors (Kledal *et al*, 2000). However, they are unlikely to be at levels in the manure that would pose a reasonable risk.

There is a lack of specific knowledge about the levels of environmental oestrogenic compounds in bovine manure and the effect this may have on human and animal health.

7.4.4 Antibiotics and antibiotic resistance genes

Antibiotic resistant forms of Salmonella, Campylobacter, *E. coli* and Listeria are either known to exist, or are suspected to exist. In food animals an increase of resistant bacteria in the faecal flora means that more resistant bacteria are excreted into the environment. Food of animal origin may be contaminated with resistant bacteria and humans acquire resistant bacteria in their intestinal flora via food (*pers comm.* Blackall, 2001).

There is emerging, but no definitive, evidence of a link between animal production facilities and infections in humans associated with antibiotic resistant bacteria. A child

in the US was found to be infected with a Salmonella resistant to 13 antibiotics. The source of infection was suggested as cattle on the family property.

Australian cattle isolates of Salmonella from the late 1970s and early 1980s were shown to have a relatively low level of antibiotic resistance – 21% resistant to streptomycin, 17% resistant to tetracycline and 7% resistant to ampicillin (Murray *et al*, 1986). This level of resistance did not show any increase over the seven year period of the study (Murray *et al*, 1986).

Overseas studies have reported that cattle isolates of Salmonella (Blackburn *et al*, 1984; Jorgensen, 1986), Campylobacter (Bradbury & Munroe, 1985) and STEC (Gonzalez & Blanco, 1989) are commonly resistant to multiple antibiotics.

The available information on the characteristics of the antibiotics used in cattle (including growth promotants and anti-coccidial agents) indicates that these agents are likely to be present at only low levels and with a short half-life in bovine manure.

7.4.5 Antibiotic resistant enterococci

Over 18 species are recognised within the genus Enterococcus (Franz *et al*, 1999). However, two species, *E. faecalis* and *E. faecium*, are the species that are strongly associated with human disease (Franz *et al*, 1999). Enterococci are of major importance in community and hospital-acquired infections (Franz *et al*, 1999). Septicaemia is the most common form of the infection.

From the early 1970s onwards, enterococci from human infections started to show evidence of acquired antibiotic resistance (Franz *et al*, 1999). A major recent concern has been the occurrence of vancomycin resistant enterococci (VRE). Vancomycin was the antibiotic of choice when treating enterococci. As well, vancomycin resistant enterococci are typically highly resistant to all standard anti-enterococcal antibiotics (Franz *et al*, 1999).

There is evidence that VRE may arise in farm animals given avoparcin, a glycopeptide antibiotic (Das *et al*, 1997). This has lead to a European Union-wide ban on the use of avoparcin (McDonald *et al*, 1997).

E. faecalis and *E. faecium* are present in cattle faeces but with a lower prevalence than in human faeces (Leclerc *et al*, 1996)

While there are reports of VRE on bovine meat products (Klein *et al*, 1998), there is little, if any, literature reporting on the prevalence of VRE in bovine faeces.

There appears to have been no publications reporting the isolation of VRE from the faeces of Australian cattle. The fact that Avoparcin is no longer registered for use as a growth promotant in cattle means that there is little likelihood of VRE occurring in bovine manure.

Overall, there is little published evidence linking bovine manure as a source of VRE that can then enter the food chain. However, few structured studies, particularly in the

Australian context, appear to have been performed. This lack of specific knowledge means that VRE cannot be ruled out totally. VRE should be regarded as a Low Priority in manure re-use applications.

7.5 ANALYSIS METHODS, LIMITATIONS AND INDICATIVE COSTS

Sampling and analysis methods for likely contaminants have been reviewed here in the context of evaluating potential monitors of quality assurance. Recommendations for indicator tests are provided in Section 10 of this report.

7.5.1 Sampling

Sampling techniques will differ depending on the contaminant, however the general procedure is to contact the testing laboratory for instructions on sampling, handling and transport of samples. For bacterial samples the collection vessel must be sterile and handling of the sample must minimise contamination. Samples must be stored and transported under refrigerated conditions, and must reach the laboratory via an overnight service. Chemical tests require similar sampling protocols.

7.5.2 Analysis

Only NATA accredited laboratories should be used for testing. The methods used for each of the identified contaminants are provided in Table 6 but may only apply to water samples. Most tests require specialised equipment and personnel and are not tests that can be done on-site.

Suitable monitors of quality assurance are discussed further in Section 10.

TABLE 6: ANALYTICAL METHODS FOR IDENTIFIED CONTAMINANTS

Contaminant	Analytical Method	Limitations Comments	Indicative cost per sample
Cyanobacteria	Membrane filtration, washed off filter into cell counting chamber for direct microscope count	Highly specialised task, very labour intensive, expertise not normally available in routine testing labs, mainly limited to specialist water and government labs	$80
E. coli (STEC)*	Membrane filtration (100mL), enrichment, immunomagnetic separation, growth on selective agar	Minimum 48 h to not detected result, if confirmation required, up to 5 days total for result.	$50
Campylobacter*	Membrane filtration (100mL), enrichment, growth on selective agars	Minimum 72 h to not detected result, if confirmation required, up to 8 days total for result.	$40
Cryptosporidium	Membrane filtration (minimum 10L), immunoflourescent stain on filter, microscope count	No standard method, recoveries not yet acceptable, less than 75%, very few labs test for it	$400
Salmonella*	Membrane filtration (100mL), enrichment,	Minimum 72 h to not detected result, if	$35

Contaminant	Analytical Method	Limitations Comments	Indicative cost per sample
	growth on selective agars	confirmation required, up to 7 days total for result.	
Yersinia*	Membrane filtration (100mL), enrichment, growth on selective agars	Minimum 96 h to not detected result, if confirmation required, up to 8 days total for result.	$40
Giardia	Membrane filtration (minimum 10L), immunoflourescent stain on filter, microscope count	No standard method, recoveries not yet acceptable, less than 75%, very few labs test for it	$400
Listeria*	Membrane filtration (100mL), enrichment, growth on selective agars	Minimum 72 h to not detected result, if confirmation required, up to 8 days total for result.	$40
Clostridium	Membrane filtration (100mL), enrichment, growth on selective agars	Minimum 24 h to not detected result, if confirmation required, up to 8 days total for result.	$40
Leptospira	Membrane filtration (100mL), enrichment, growth in selective broth, dark field microscopy	Usually detected in 14 days if present, but incubate up to 6 weeks if not detected. Few bacteria	Unknown but likely to be >$100[1]
Coxiella	Adaptation of isolation from clinical specimens, most likely Membrane filtration (minimum 1L), immunoflourescent stain on filter, microscope count	Is a class 3 pathogen, therefore requires significantly restrictive handling procedures. Only normally tested for in medical labs. Routine water labs unlikely to have class 3 capability. Is normally aerosol transmission anyway	Unknown but likely to be >$100
Enterococcus (AB resist)	Membrane filtration (100mL), enrichment, growth on selective agars.	Minimum 48 h to not detected result, if confirmation required, up to 7 days total for result. Enterococcus is a routine test, but antibiotic resistance is not yet routine	$40
Mycotoxins	Minimum of three step extraction, HPLC fluorescent detection	Very difficult to extract, different mycotoxins will require different clean-up and extraction steps, as no one set of steps will extract all mycotoxins. Very few labs have the capability.	Unknown but likely to be >$300
Mycobacterium avium	Membrane filtration (500mL), acid fast stain, selective bactericidal treatment, growth on selective agar, check weekly for 8 weeks	Takes up to 8 weeks but normally detected in 3 weeks if present. Not a very reliable test. Effort going into PCR method development, mainly restricted to clinical labs	Unknown but likely to be >$100

[1] "Unknown" means that only human pathological analysis is currently undertaken, but no environmental analysis. Laboratories are reluctant to test environmental samples in pathology laboratories.

Contaminant	Analytical Method	Limitations Comments	Indicative cost per sample
HGP	Minimum 3 step clean-up and extraction, GCMS. Would be adaptation of flesh (liver) method	Very few labs capable, very few of the HGPs have methods developed for detection	Unknown but likely to be >$300
Viruses	Adsorption onto microporous filters using pressure vessels, 12-20L capacity with relief valves, concentration, assay in relevant host system (usually cell culture lines although some will require bio-assay) appropriate to each virus target . No one host system can be used for all viruses	Not recommended for routine testing. Very few laboratories capable of virus detection. Normally only government funded large comprehensive labs or universities or CSIRO capable	Unknown but likely to be >$250
Worms	Sieve at least 1L, microscopic examination	Highly specialised task, expertise not normally available in routine testing labs	Unknown but likely to be >$200
Lice	Sieve/filtration, microscopic examination	Highly specialised task, expertise not normally available in routine testing labs	Unknown but likely to be >$200
Heavy Metals (Copper, zinc, cadmium, chromium, arsenic, lead, mercury, nickel	Chromium – colourimetric titration Mercury – Mass Spectrometer (MS) Remainder – Atomic Emission Spectrometry (AES)	Standard methods, relatively easy to carry out. For solids also need moisture as data reported as dry weight, most chemistry labs capable	Suite of complete list $75 water and $110 solids
Nitrate	Ion Chromatography	Standard method, fairly simple test, most chemistry labs capable	Water $15 Solid $20

* Confirmatory tests for common pathogens average at $25 per test however some laboratories may provide the test at no additional cost depending on the frequency of sample analysis from individuals.

8. RISK ASSESSMENT

8.1 RISK IDENTIFICATION

Using the potential transfer paths identified in Section 6, and the contaminants identified in Section 7, we have identified all risks, regardless or not of whether they are under the control of the feedlot (Table 7). This comprehensive list is used as the basis on which to conduct the risk assessment.

TABLE 7: RISK AND TRANSFER PATH FOR RISK ASSESSMENT

Description of risk and transfer path
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.

8.2 RISK ASSESSMENT METHODOLOGY

As per AS/NZS 4360:1999, risk assessment separates the minor acceptable risks from the major risks. Risk assessment, depending on what data is available can be

1. Qualitative;
2. Semi-quantitative; or
3. Quantitative.

Ideally, quantitative risk assessment is best suited for these types of studies. Quantitative Microbial Risk Assessment (QMRA) has been used in many studies to assess, without resorting to the use of human volunteers, the risk to human health from compounds such as pathogens, carcinogens and toxicants (Blackall et al, 2000). It quantifies values for infection so risks can be ranked.

The four basic steps for QMRA are (Blackall et al, 2000):

(a) **Hazard identification**
An identification of those pathogens potentially present in the effluent that may have an adverse effect on human health. Identification and enumeration (as colony forming units per 100 ml) is an example of hazard identification.

(b) **Exposure assessment**
In this phase, the number of organisms to which individuals and populations are exposed is estimated. The route of exposure (aerosol, oral ingestion etc), the duration of exposure, the concentration of the pathogen in the carrier (aerosols, dust, liquid) the amount of carrier ingested/inhaled, and the frequency of exposure are used to estimate the ingested pathogen dose.

(c) **Dose-Response assessment**
This step involves a quantification of the relationship between the number of pathogens ingested and the percentage of the population that becomes infected. As an example, the ID_{50} is the dose of a particular pathogen required to infect 50% of the test population. There are many factors that affect the dose response – the type of pathogen, the age of the human host and the level of pre-existing immunity of the host.

(d) **Risk assessment**
In this stage, all of the information gathered in the first three stages is assembled and the potential for infection is quantified, usually as infections/10,000 people/year.

Computer models can be developed to assess the risks as above.

QRMA is only as effective as the data which are placed into it. They are performed with a detailed knowledge of the actual levels of pathogens present and knowledge of how those pathogens are transported or disseminated. In this study, we do not have that detailed knowledge, therefore this type of risk assessment can not be performed. While for **some** pathogens we have overseas data on the likely levels, it is unlikely that these levels are comparable with the Australian situation.

Vanselow & Hornitzky (2001) did not quantify the levels of pathogens in waste. In addition, they stated that Australian data could not be compared with overseas data because the makeup of pathogens in Australian manure was different to that overseas.

8.3 PROJECT APPROACH TO RISK ASSESSMENT

Both qualitative and semi-quantitative methodologies consider the “likelihood” and “consequence” of the risks. In semi-quantitative risk assessment, likelihood is usually composed of two elements - frequency of exposure and probability (Standards Australia 1999). Frequency of exposure is the extent to which a source or risk exists and probability is the chance that when that source of risk exists, consequences will follow.

While we are aware of what causal agents might exist, we do not know the extent of the risk. Likewise, little Australian data exists on what consequences may arise if that risk is there.

The methodology used in this project, has been adapted from “Risk Assessment in Food Safety Policy and Practice” (Bureau of Resource Sciences) to provide a semi-quantitative analysis for assessment of risks for feedlot waste products. The assessment was performed separately for both animals and humans.

HAZARD IDENTIFICATION

1. Is the agent capable of causing adverse health effects?

Response	Definition	Score
No	No illness	0 (do not proceed any further)
Yes	The literature has documented cases of the agent causing an adverse health effect (from any source).	1
Don't know	There is no clear evidence whether the agent causes an adverse health effect.	Stop at this point

2. What are the consequences and severity of adverse effects?

Response	Definition	Score
Mild	Only results in minor complaints	0.1
Major	Could require medical attention	0.5
Severe	Can result in death	1
Don't know	There is no literature which details adverse effects	Stop at this point

EXPOSURE ASSESSMENT

3. What is the likelihood of contamination?

Response	Definition	Score
Low	▪ The causal agent has been found in waste product but is unlikely to survive in the waste product or end product	0.1
Medium	▪ The causal agent has been identified in waste product; **or** ▪ Epidemiological studies have implicated exposure to manure or waste products and the transfer path as a high risk	0.5
High	▪ The causal agent has been identified in waste product; **and** ▪ Epidemiological studies have implicated exposure to manure or waste products and the transfer path as a high risk	1
Don't know	There is no literature which determines whether the waste product is contaminated and/or there is no epidemiological studies.	Stop at this point

Note: A waste product or end product is defined as solid manure, effluent or any product consisting of these elements, whether treated or not.

4. Will process steps (critical control points) reduce the hazard to acceptable levels?

This question is specific to the feedlots (management practices) and will assist in reducing the risk. For example, the risk of contamination of food crops with zoonotic pathogens will be reduced if properly composted material is used (as opposed to a transfer path of non-composted manure or improperly composted material applied to food crops or irrigation of effluent water onto crops).

This question was not included in the risk assessment at it is specific to feedlots.

5. Will the end-use reduce the hazard to acceptable levels?

This question is specific to the feedlot and will assist in reducing the risk. Using the example in 4, the risk may be acceptable if the end user applies the waste to a product which will not come into contact with the crop itself or which is not shown to be transferred to the product through other mechanisms.

Overall Rating

The factors in Q1, 2 and 3 will be multiplied.

1 will be a high risk and is defined as:

- There is a high likelihood that the risk will occur and it will result in serious consequences (eg death of a human or animal).

0.25 - 0.5 will be a medium risk and is defined as:

- There is a risk that a hazard will occur which may result in serious consequences; or
- There is a high likelihood of severe consequences by only a medium level of likelihood of contamination of the product; or
- There is a high likelihood that the product will be contaminated resulting in illness which may require medical attention.

Both medium and high risks will require action, meaning that the hazard will require some control.

0.1 or below will be a low risk

- There is a medium-high likelihood that the product will be contaminated but the consequence will not be severe; or
- There is a low chance that the product will be contaminated, but if it is, the consequence will be severe.

Results of the risk assessment are presented in Section 8.4.

8.4 RESULTS OF THE RISK ASSESSMENT

A summary of the results of the risk assessment for each causal agent based on the methodology outlined in 8.3 is presented in Table 8. Detailed rationale for the selections are provided in Appendix 1.

TABLE 8: RISK ASSESSMENT

Description of risk and transfer path	Target	Campylobacter	E. coli (STEC)	Salmonella	*Coxiella burnetti*	Leptospira	Listeria	Yersinia	Clostridium
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	Medium	High	Medium	Unknown	Medium	Low-medium	Unknown	Low
	Cattle	No risk	No risk	High	No risk	Unknown	Low-medium	Unknown	Unknown
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	Medium	High	Medium	Unknown	Medium	Medium	Unknown	Low
	Cattle	No risk	No risk	Medium	No risk	Unknown	Medium	Unknown	Unknown
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals	Humans	Unknown	Unknown	Medium	Medium	Unknown	Unknown	Unknown	Low
	Cattle	No risk	No risk	Unknown	No risk	Unknown	Unknown	Unknown	Unknown
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	Medium	High	Medium	Unknown	Medium	Medium	Unknown	Medium
	Cattle	No risk	No risk	High	No risk	Unknown	Medium	Unknown	High

Continued over

Description of risk and transfer path	Target	Mycobacterium	Mycotoxins	Cryptosporidium	Giardia	Heavy Metals	Hormones and Endocrine Disruptors	Antibiotic resistance
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	Unknown	Not applicable	Medium	Medium	Low	Unknown	Unknown
	Cattle	High	Not applicable	Low	Low	Low	-	Unknown
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	Unknown	Not applicable	Medium	Medium	Low	Unknown	Unknown
	Cattle	High	Not applicable	Low	Low	Low	-	Unknown
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals	Humans	Unknown	Unknown	Unknown	Unknown	Low	Unknown	Unknown
	Cattle	Unknown	Unknown	Unknown	Unknown	Low	-	Unknown
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	Unknown	Unknown	Medium	Medium	Medium	Unknown	Unknown
	Cattle	High	Unknown	Low	Low	Medium	-	Unknown

Without considering feedlot best practice, or actual practices, the high risks have therefore been identified and summarised in Table 9. For humans *E. coli* (STEC) is the contaminant of concern. For cattle, the causal agents of concern are Salmonella, Mycobacterium and Clostridium. Paths of transfer include contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking; contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals; and direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.

TABLE 9: SUMMARY OF HIGH RISKS

Description of risk and transfer path	Target	Causal Agent
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	*E. coli* (STEC)
	Cattle	Salmonella Mycobacterium
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	*E. coli* (STEC)
	Cattle	Mycobacterium
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals.	Humans	-
	Cattle	-
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	*E. coli* (STEC)
	Cattle	Salmonella, Clostridium and Mycobacterium

There are significant unknowns in this risk assessment, particularly with assessing risks associated with air-borne transmission. Table 8 identifies all causal agents where a definitive assessment could not be made (named "Unknown") and therefore can not totally be dismissed as no risk.

9. FEEDLOT PRACTICES IMPACTING ON TRANSFER OF CONTAMINANTS

This section of the report deals with assessing feedlot practices in order to design risk minimisation strategies.

9.1 FEEDLOT PRACTICES IMPACTING ON TRANSFER OF CONTAMINANTS

Five main feedlot practices impact on contaminant transfer as detailed in Table 10. Further information on each practice is provided in 8.1.1 to 8.1.6, including practices which best minimise implications for human and animal health.

TABLE 10: FEEDLOT PRACTICES AND IMPLICATIONS

Management Practice	Implications for Human and Animal Health
Site plan and location of feedlot	
Runoff and seepage from pens	Contamination of water supplies (N and P, heavy metals, chemical residues, pathogens)
Importation of new animals	
Prophylactic treatment of cattle (vaccinations, antibiotics, drenches)	Waste may contain antibiotic or pesticide residues
Transitional feeding of cattle onto grain-based diet	Increased shedding of zoonotic pathogens in stressed animals contributing to increased microbial loads in the waste.
Routine management of cattle	
Selection of feed ration	Infection of animals via contaminated feed
Application antibiotics as growth promotants	Antibiotic resistant microorganisms in waste
Management of sick animals	Therapeutic treatment and pesticide residues, management of animal mortalities
Removal of manure from pens	
Depth of manure and frequency of mechanical removal	Survival of pathogens in pens and potential for contaminating meat during slaughter and processing
Stockpiling of manure either in or out of pens	Survival of pathogens, potential for leaching contaminated water into water supplies
Retention of stormwater flow from pens	Potential build-up of pathogens during storage, fate of chemical residues in solid and liquid phases of pond

Management Practice	Implications for Human and Animal Health
Reuse of manure and wastewater	
Application of manure to cropping or pasture land	Survival of pathogens, bioavailability of chemicals, and contamination of food plants and/or water supplies
Pelletising manure	Survival of pathogens, degradation of and bioavailability of chemicals
Composting manure	Survival of pathogens, degradation of and bioavailability of chemicals
Vermicomposting manure	Survival of pathogens, degradation of and bioavailability of chemicals
Irrigation of wastewater from stormwater retention basin	Survival of pathogens, degradation of and bioavailability of chemicals, generation of aerosols, contamination of water supplies

9.1.1 Design and siting of feedlot

9.1.1.1 Topographic location in the landscape

Topography is critical in reducing the risk of contamination of surface water with manure. During high intensity storm events a substantial proportion of fine manure particles can be transported downslope (Gilbertson *et al*, 1971). Most of the nitrogen and phosphorus in these particles is in the organic form (Sharpley & Moyer, 2000; Eghball *et al*, 1997), given that much of the ammonia excreted in the urine is volatilised from the pad. However once these particles enter surface water bodies they add to the nitrogen and phosphorus concentrations, increasing the risk of toxic algal bloom formation (Bowmer & Laut, 1992; Blackmore & Connell, 1997).

The cattle industry has responded to these risks by recommending topographic guidelines for the design and construction of feedlots (Skerman, 2000). To control runoff the pen area should have a slope within the range of 2.5 to 4%. Each module of pens should be located on a sufficiently uniform slope, to enable drainage towards a holding pond. Holding ponds should be sized to accommodate at least a 1 in 20 year, 24 hour storm event. The pond should be capable of holding runoff from the drainage area typically generated in a 90 percentile wet year. The storage volume of the holding pond system should be sufficient to ensure that over-topping (spillage) does not occur any more frequently than 1 in 10 years. The ponds should also be desludged at regular intervals to maintain the effective capacity, and storage levels should be reduced to less than 20% of the full capacity before the start of the wet season. Risks associated with the reuse of the sludge and irrigation will be covered in a later section.

The Guidelines also recommend the maintenance of a buffer between the feedlot complex and streams, rivers and other watercourses. However no specifications are given as the effectiveness of the buffer will vary with site-specific factors such as topography, vegetation, natural gradient, and management practices. Vegetated buffers of a minimum width of 2 m adjacent to water courses have been recommended in areas prone to any soil loss, in the Code of Practice for Queensland Irrigators (Karssies & Prosser, 1999). The maximum width is

determined by the slope of the filter zone, and the amount of soil potentially lost from the site per year. Typical values for annual soil loss are calculated using a Universal Soil Loss Equation (USLE). Rainfall erosivity, soil erodibility, slope length and gradient, extent of cover and crop management practices and the type of supporting practices used, are components of the USLE. For irrigators in areas where the estimated soil loss is greater than 50 t/ha/y, the recommended filter strip width may exceed 30 m.

However in the literature the concept of a vegetated filter strip has also been used as a wastewater treatment system. Vegetated filter strips are common components of industry Best Management Practices for the protection of water resources (Clausen & Meals, 1989). Confusion arises when the function of the strip changes from a no-go buffer (eg Karssies & Prosser, 1999; MAFF, 1998), to a wastewater treatment system (eg Schwer & Clausen, 1989). As a consequence the effective width of the strip changes from 50 m or so, to greater than 250 m. Accordingly, when making recommendations on the width of vegetated filter strips, the function of the strip must be clearly defined.

9.1.1.2 Soil type and proximity to the water table

Nitrogen loss through leaching of nitrate and ammonium down the soil profile can lead to increased nitrate concentrations in groundwater drinking supplies (Hooda *et al*, 2000). In soils that are deeply cracked, highly permeable, or where the water table is close to the surface, the risks of nitrate, pesticide, and/or pathogen contamination of groundwater increase substantially.

Protected in the manure sediment, bacteria can be transported in water down the soil profile to groundwater (Johnson & Logan, 1996). A shorter route for the transport of contaminants to groundwater supplies is via the casings of poorly constructed water wells or bores (Goss *et al*, 1998). In a study of the incidence of contamination of farmstead domestic groundwater wells in Ontario Canada, the percentage of wells contaminated by coliform bacteria decreased significantly as the distance between the well and the feedlot or animal exercise yard increased.

The reference manual for the management of cattle feedlots addresses the protection of groundwater by recommending that the pen area should be constructed on a compacted, smooth, well drained site (Skerman, 2000). All runoff from the feedlot should be caught in drains, and stored in a holding pond. The following areas are considered unsuitable due to the increased risk of leaching and of contaminating the subsurface environment:

- Rocky areas
- Areas where natural springs occur
- Areas with highly expansive heavy clays
- Areas with light sandy soils

Buffers to bores have not been indicated, but in the British Water Code a buffer of 50 m between any manure application area and a well, spring or bore used for human water consumption should be maintained (MAFF, 1998). In this context, the buffer is defined as a zone onto which no manure, slurry or irrigated effluent will be applied. Such buffers are commonly covered with perennial pasture, with the plants trapping any sediment transported during storm events.

Additional protection of the subsurface environment is also implicit in the recommendations for the preparation of the surface of the feedlot pad, and for the lining of drains, sedimentation systems, holding ponds and manure stockpile areas (Skerman, 2000). The specifications ensure that a smooth, impermeable surface will result, minimising the risks of leaching. Recommendations on the management of manure within the pens are also designed to minimise the risk of leaching, by keeping the surface seal intact. In practice, over time the particle fractions in the manure disperse and settle out, with the compacting force of the cattle hooves produce an impermeable surface seal (Mielke & Mazurak, 1976). Provided that this surface seal is not disturbed during pen cleaning operations, the risk of nutrients and microbial contaminants leaching into the subsurface layer below the pens is minimal. For this reason, most feedlots scrape manure from pens when a depth of 50 to 80 mm has developed, always leaving a depth of at least 25 mm to protect the seal at the soil/manure interface.

9.1.2 Importation of new animals into feedlot

9.1.2.1 Importation of animals

Cattle are considered the primary reservoir for several zoonotic pathogens in the environment (Bettelheim, 1996; Donnelly & Stentiford, 1997; Jones, 1999). Calves tend to shed more of these pathogens than older animals. Most beef cattle feedlots function as a finishing operation, accepting older animals that are less likely to be carriers of these pathogens.

Older cattle show seasonal fluctuations in their excretion rate of bacterial pathogens, with stressed animals much more prone to infection. Practices such as a change of diet, and intermittent feeding associated with animal transportation disrupt the normal microbiological processes in the rumen, rendering the animals more prone to infection (Grau, 1989; Jones, 1999). Accordingly, recently arrived cattle should be viewed as a source of infection for the feedlot and likely to increase the loading of pathogens in waste.

9.1.2.2 Prophylactic and therapeutic treatment of cattle

Feedlots typically maintain a relatively high density of animals, increasing the risk of infectious disease outbreaks. To minimise this risk, recently arrived cattle often undergo vaccination programs and therapeutic treatment with antibiotics or other pesticides. In Queensland the 5-in-1 vaccination against Clostridial diseases is mandatory, as is lice treatment, liver fluke treatment, and the treatment of cattle showing symptoms of shipping fever and transit tetany (Cronin, 2001). Bush fly, tick and worm treatment is recommended but not necessarily essential, as is the use of hormonal growth promotant. Vaccination against leptospirosis is optional, as is the treatment of cattle for three-day sickness.

In Australia, there are restrictions on the subtherapeutic use of antibiotics, due to the risks of generating zoonotic pathogens resistant to antibiotics (Franco *et al*, 1990).

9.1.2.3 Transitional feeding of cattle onto grain-based diet

Disruptions to feeding patterns such as changes in the diet and in the timing and availability of feed disrupt the normal microbiological functions in ruminants. As a result recently arrived cattle are prone to diseases such as bloat (Cheng *et al*, 1998), and liver abscesses (Nagaraja & Chengappa, 1998). In addition, the incidence of Cryptosporidium, enterohaemorrhagic *E coli*, Campylobacter, Salmonella, Clostridium and leptospiral bacteria in the intestinal tract is also likely to be greater (Bettelheim, 1996; Donnelly & Stentiford, 1997; Jones, 1999; Losinger *et*

al, 1997). To reduce the incidence of disease and the risk of spreading infection, transitional feeding programs are implemented. The amount of roughage, grain processing techniques, selection of cereal grain, dietary adaptation periods, and the addition of mineral and bacterial modifying supplements are used to acclimatise the cattle onto the feedlot diet regime. After this transitional phase the animals have adjusted to the grain-based diet, and pose little threat to the rest of the feedlot herd.

9.1.3 Routine cattle management within the feedlot

9.1.3.1 Composition of rations fed to cattle

Components of the ration fed to cattle include grains, silage, haylage, green chop, roughage, legume hay, cottonseed by-products, molasses, tallow, protein meals (excluding mammalian-derived material), and a number of additives fed as a premix (Sneath & Wood, 2001). Important minerals and vitamins include phosphorus, calcium, sulphur, potassium, sodium, vitamins A and E, and other trace elements.

9.1.3.2 Feed rations and mycotoxin poisoning

Feeding contaminated grains, haylage, green chop and hay may cause mycotoxin poisoning in cattle. Ensuring the quality of incoming feed is an important risk minimisation strategy and is addressed in quality assurance programs such as the NFAS.

9.1.3.3 Feed rations and heavy metal contamination in manure

The feeding of mineral supplements to lot-fed cattle is largely in the form of inorganic salts such as limestone, muriate of potash, bentonite, or phosphates (Sneath & Wood, 2001). Trace minerals such as magnesium, chlorine, copper, iron, cobalt, selenium, iodine, zinc and manganese are usually administered as a commercially prepared formulation added at about 0.1% by weight of the ration. Bore water supplied to the cattle may also be another source of dissolved minerals including sodium. Nutrients in excess to cattle requirements are excreted in the faeces. As mentioned in the literature review, concern has been expressed about the repeated use of cattle manure as a fertiliser for growing crops. Applications of phosphatic fertilisers to crops are recognised as a source of the contaminant cadmium (Hamon *et al*, 1998). Depending on the purity of the salts used in the feed ration, manure is also a potential source of heavy metal contamination (Xue *et al*, 2000).

In practice, setting limits on the acceptable level of heavy metal contaminants present in supplies of limestone and phosphate added to feed formulations, and ensuring that the addition of trace mineral supplements is strictly in accordance to cattle requirements, will minimise the concentrations of heavy metals excreted in cattle faeces.

9.1.3.4 Occupational health and safety issues for workers in feedlots

Of the occupational health issues facing workers at cattle feedlots, leptospirosis and Q fever pose a potential risk. In both cases the prevention of inhaling contaminated dust or fluid droplets (aerosols), exercising good personal hygiene, and covering cuts and abrasions with water-proof dressings will minimise the risk of infection. Workers who have not naturally acquired immunity can be vaccinated against Q fever, and cattle can be vaccinated against leptospirosis to further reduce the risk of workers contracting these diseases.

9.1.4 Waste management practices within the feedlot

9.1.4.1 Mechanical removal of manure and management of stockpiles

Recommendations on the management of manure within feedlot pens are designed to minimise the risk of leaching, by keeping the surface seal intact. In practice, over time the particle fractions in the manure disperse and settle out, with the compacting force of the cattle hooves producing an impermeable surface seal (Mielke & Mazurak, 1976). Most feedlots scrape manure from pens when a depth of 50 to 80 mm has developed, always leaving a depth of at least 25 mm to protect the seal at the soil/manure interface. The manure is stockpiled on-site, prior to the local reuse of the raw product or further processing.

In Queensland the requirements for the preparation of the site for stockpiling and composting are similar to those for the feedlot pens. The site should be compacted, on a gentle slope of 1 to 3%, with all surface drainage over the site contained within an appropriately sized holding pond (Skerman, 2000). The manure placed in a stockpile for longer term storage should be compacted, to expel air which may induce spontaneous combustion. The shape of the stockpile should be designed to avoid ponding during rain. The requirements for site preparation and management in the cattle feedlot code (Skerman, 2000) include adequate buffer distances for odour abatement. These buffers could provide an opportunity for sufficient aerosol dispersion of contaminants but this is not known.

9.1.5 Reuse of untreated manure and wastewater for agriculture

9.1.5.1 Manure application to land

i. Protection from zoonotic pathogens

The risk of groundwater contamination with microbial pathogens that may be present in manure is greatest where manure or pond effluent is applied in close proximity to water wells or bores (Goss *et al*, 1998), or onto land classed as groundwater vulnerable (ANZECC, 1995).

The maintenance of vegetated buffer strips onto which no manure or effluent is applied, should minimise the likelihood of groundwater and surface water course contamination. Site-specific criteria have been included in the design of buffer strips for riparian zones for irrigation purposes in Queensland (Karssies & Prosser, 1999). However the application of manure in both the solid and liquid form can lead to the temporary clogging of soil pores (Nunez-Delgado *et al*, 2001). As a consequence, following the first rains after manure application, surface run-off may be greater for land onto which manure has been applied relative to the application of inorganic fertiliser. The width of buffers for the protection of ground and surface water supplies may need to be greater when manure is applied, than those calculated for conventionally irrigated and fertilised soils.

ii. Protection from nitrite poisoning and algal blooms

To be environmentally sustainable in the long-term, applications of manure to land should be scheduled to meet the crop nutrient requirements for growth (Barkle *et al*, 2000). On the basis of their total nutrient concentration, animal manures offer attractive alternatives to inorganic fertilisers. For example the nitrogen fertiliser equivalent in the excreta produced annually by 400,000 pigs in South Australia could hypothetically fertilise about 200,000 ha of cereal

crops (Brechin & McDonald, 1994). However in cattle manure, a high proportion (up to 50%) of the excreted ammonium nitrogen is volatilised during aerobic storage on the feedlot pad (Eghball *et al*, 1997).

Hence most of the nitrogen in stock-piled cattle feedlot manure is in the organic form, unavailable for plant growth. By definition, in the first year of application conventional nitrogenous fertiliser may need to be applied in addition to the manure. However if the rate of mineralisation of the nitrogen in the applied manure is not accounted for in the application of fertilisers in subsequent years, excess nitrate will leach from the soil. Even if application rates to soil are based on nitrogen availability both in the manure and in the soil, the accumulation of phosphorus is likely to be excessive (Sims, 1995; Smith *et al*, 1998).

Compared to the ratio of plant requirements for nitrogen and phosphorous, the concentration of phosphorous in organic wastes of animal origin is twice to three times as great as the concentration of nitrogen. As with nitrogen, most of the phosphorous is bound in the organic fraction, associated with very fine solids. The results of more recent studies indicate that the movement of organically bound phosphorous in overland flow is greater than was previously thought (Menzies *et al*, 1999; Sharpley & Moyer, 2000). Excess nitrate and phosphorus increases the probability of nitrite poisoning of groundwater, and/or algal bloom stimulation in surface waters (Blackmore & Connell, 1997; Bowmer & Laut, 1992).

The implementation of appropriately sized vegetated buffer strips adjacent to water courses and water wells or bores will reduce the risks of surface and ground water contamination in the short-term (refer previous section). However in the longer term, the rate of application of nutrients to cropping soils and the rate of nutrient removal at harvest must be considered. In Queensland, recommended application rates for feedlot manure vary from 10 to 15 tonnes per hectare for dryland, to 20 to 30 tonnes per hectare for irrigated grain crops (Powell, 1999). Feedlot manure with a moisture content of between 25 to 30% is considered optimal for spreading purposes. These recommendations do not account for the difference in plant-availability of nutrients in manures of different animal origin, and do not address the importance of subsequent soil testing for assessing nutrient availability over time after application (Van Kessel *et al*, 2000).

In feedlot cattle manure, potassium (K) is the most readily available nutrient (about 80% of the total K concentration: Pittaway & Roberts, 2000). Both phosphorus and nitrogen may largely be in the organic form, unavailable for plant uptake. During the first few weeks after soil application, nutrients in available form in the manure may be taken up by soil microbes (nutrient draw-down or immobilisation). The duration and severity of nutrient immobilisation varies with manure management practices, such as stockpiling (Atallah *et al*, 1995).

Applying the manure close to the time of sowing of the crop is problematic, as this may coincide with the nutrient immobilisation phase. Nutrient immobilisation coincident with crop germination and emergence may add to the crop stresses, inducing germination failure and/or proneness to plant diseases. Over time this process is reversed, with nutrients released in the plant-available or mineralised form (slow-release fertiliser effect). Relative to other manure sources, the time of onset of mineralisation in cattle manure is much later (Gagnon & Simard, 1999). Under controlled conditions of composting, the processes of immobilisation and mineralisation are enhanced, producing a much more stable and agronomically useful product (Pittaway & Roberts, 2000).

Therefore, application rates for fresh cattle manure should be based on the upper limit of the crop's requirement for potassium. In the first year of application, rates of inorganic nitrogen and phosphorus fertiliser should be reduced according to the plant availability of nitrogen and phosphorous in the manure. More importantly in subsequent years, as the nitrogen and phosphorous contained in the manure mineralises, soil testing must be carried out to further reduce the application of conventional nitrogen and phosphorous fertiliser. Under these management practices, the risks of ground and surface water pollution will be minimal.

9.1.5.2 Manure application to crops: implications for food safety

i. Microbial contamination

Minimally processed fruits and vegetables are defined as fresh, raw fruits or vegetables processed to supply a ready-to-eat or ready-to-use product (Nguyen-the & Carlin, 1994). Processing prior to consumption is normally restricted to trimming, peeling, or cutting. Some are washed, and less commonly, some will be disinfected. However the presence of cut surfaces, and the fresh physiological state of the produce renders them prone to contamination with potential foodborne pathogens.

Risk minimisation techniques employed by growers include imposing pathogen limits, resting periods and solarisation. The vegetable industry has recently commissioned a project to evaluate the microbiological safety of current manure management practices in Australian vegetable production systems to evaluate food safety hazards. On the basis of this study, manure management guidelines specific for growing vegetables under Australian conditions will be developed.

Nevertheless, feedlots must carefully consider the end market when supplying waste products, in particular only supplying materials that have been sufficiently treated to minimise pathogen presence.

ii. Contamination with heavy metals

The best strategy for avoiding heavy metal accumulation in soils subjected to repeat applications of livestock manure is to account for the current heavy metal status of both the receiving soil, and that of the fertiliser or soil conditioner to be applied (Moolenaar *et al*, 1997a). Where the concentrations present in either the soil or the manure are close to or exceed the recommended upper limits, a mass balance should be conducted to assess the bioavailability of the metals of concern and thus minimise the risk of heavy metal accumulation in the longer term (McLoughlin *et al*, 2000).

9.1.5.3 Effluent irrigation from feedlot holding ponds

Holding ponds for run-off from feedlots generated during storms function as anaerobic ponds. In the dairy and piggery industries anaerobic ponds have been designed for odour abatement, not for the recovery and reuse of nutrients and not for the control of pathogens. Salmonella and other coliform pathogens can survive and multiply during anaerobic storage (Gibbs *et al*, 1995; Henry *et al*, 1995). The fates of slurries produced from cattle are of particular concern, due to their role as hosts of both Cryptosporidium and enterohaemorrhagic *E. coli* (Bettelheim, 1996; Donnelly & Stentiford; 1997). Moreover the

survival of such pathogens after the application of slurry to land is higher than previously considered, due to the protective effect of the organic solids (Toze, 1997).

Therefore water from feedlot holding ponds should not be applied to crops that are marketed as minimally processed produce. Adequate buffer distances should be implemented for the irrigation of effluent close to watercourses and groundwater bores (refer previous section).

9.1.5.4 Pelletising manure for agricultural application

Uncomposted animal manure is very cloddy and the water content can be very high, making transportation expensive and the accurate broadcasting to land almost impossible. Pelleting involves reducing the water content and particle size of manure, compressing the material into cylinders of uniform length and diameter (Hadas *et al*, 1983). During compression the temperature in the pellets reaches around 70°C for 5 to 10 minutes, effectively pasteurising the microbial population present. However microbes within the organic core of the pellet remain viable. The resultant product stores readily, is less costly to transport, and can be broadcast or fed through conventional fertiliser application systems more accurately.

Laboratory studies indicate that the ammonium concentration in pelleted manure is greater than that of ground, unpelleted manure (Hadas, 1983). The reason for this is the death and subsequent mineralisation of microbial cells (Powlson & Jenkinson, 1976). Thus nitrogen in pelleted manure is mineralised at a faster rate than that of the raw manure, after application to soil. Some established manufacturers add conventional NPK and micronutrients to overcome the lack of availability of nutrients in the raw product (EcoRecycle, 1999).

In a study comparing the growth response and potential for nutrient leaching in containerised nursery plants, pelleted chicken manure (Dynamic Lifter) provided the poorest growth response when compared to a slow-release inorganic fertiliser (Osmocote), and a liquid carnation formulation (Huett, 1997a). The rate of leaching of potassium and phosphorus from the pelleted manure product was also higher (Huett, 1997b). Most sales are to the less discriminating home garden, recreational parks and sporting reserve urban markets, where high analysis fertilisers are less commonly used. Expanding markets into the larger, agricultural sector is less likely, due to product variability and poor net present value relative to conventional fertilisers.

9.1.5.5 Composting manure

Thermophillic composting is accepted as a critical control method for the disinfection of potential pathogens in animal-based composts (Haug, 1993; Bollen & Volker; 1996). Specialist composting microbes can tolerate elevated temperatures, but above 70°C moist heat can be lethal to the general microbial community (Madigan *et al*, 1997). The aeration and water content required for microbial growth, is regulated by the bulk density of the compost medium. Heavy, fine particles compact very easily, producing many very fine pores capable of holding water under pressure. The presence of water in such mixes is at the expense of air.

Feedlot cattle manure has a high bulk density, contributing to a high water holding capacity (Pittaway, 2001d). Accordingly, there is a very fine tolerance between optimal water and aeration, and saturation leading to anaerobic conditions. Under anaerobic conditions the proliferation of potentially pathogenic coliform bacteria (for example Salmonella and enterohaemorrhagic *E coli*) is more likely (Soares *et al*, 1995). In straight manure composts,

windrows should be kept low in height and turned more frequently to provide adequate aeration for microbial growth. Windrows or stockpiles of excessive height run the risk of producing an anaerobic core, where pathogen regrowth and/or microbial methane production may occur. When these combustible gasses diffuse to the hotter, aerated interface at the outer edges of the windrow, spontaneous combustion may occur (Hogland *et al*, 1996).

However in the absence of additional bulking agents or chemical amendments, manure composts that are turned frequently lose more N and S through volatilisation (Kirchmann & Witter, 1989; Kithome *et al*, 1999), increasing the risk of odour generation. Accordingly, the selection of compatible raw materials should not only be made on the basis of their chemical composition (carbon, nitrogen, phosphorous, potassium), but also on their physical composition (bulk density and water holding capacity).

Fungi in general are more tolerant of dry conditions, but genera and species have different optimal ranges for activity and spore germination. Typically when water is not limiting, bacteria outcompete fungi (Insam *et al*, 1996). Concerns expressed about high spore populations of *Aspergillus* species in composts, the cause of the lung disease aspergillosis in farm workers, may reflect the fact that many composts are too dry to favour bacterial activity. Moreover for disinfection purposes, the combination of elevated temperatures (45-65°C) and adequate moisture (field capacity) will selectively kill potential human and plant pathogens (Pittaway & Roberts 2000). At these temperatures the activity of thermotolerant compost specialists – both fungi and bacteria are favoured, making reinfestation by potential pathogens less likely (Insam *et al*, 1996; Bollen & Volker 1996; Soares *et al*, 1995). However above 65°C many of these beneficial species may be killed, with regrowth by potential human pathogens more likely (Soares *et al*, 1995).

Some guidelines refer to the regrowth potential of zoonotic pathogens in manures and composts. However the conditions favouring regrowth are not necessarily indicated, and tests for measuring regrowth are not included (refer to Section 9.1 for further information).

If the feedlot's composting plan includes both temperature and moisture monitoring (watering to field capacity), then the specification of composting to the point of biological stability (maturity) is achievable. Provided that there is sufficient water available for microbial growth (field capacity equivalent), the temperature within the windrow prior to turning is a very good index of the composting process. Once the windrow fails to re-heat after turning, despite the maintenance of adequate available water, then the compost has reached biological stability.

9.1.5.6 Vermicomposting manure

Vermicasts are the waste products of earthworms excreted by some species at the soil surface (Shipitalo & Protz, 1989). In such species, chemical analysis of the casts gives a good indication of changes directly caused by the worms. Unfortunately compost worms do not separate their casts from the medium around them. Therefore the term vermicompost (casts integrated with other biologically processed material) is a more accurate description of the product. Worms are animals, and like other intensive livestock operations their environmental conditions and feed rations must be managed to maximise worm production. Compost worms cannot tolerate temperatures in excess of 25°C, and as a consequence the microbial processes are not the same as conventional composting (optimal temperature range 45-65°C: Edwards & Bohlen, 1996). Worms are much larger than most of the other organisms in the compost, and are capable of physically pushing particles apart as they move through the medium.

Therefore, a well-worked vermicompost will have a much smaller, more even crumb structure than that of a mid-range temperature compost (mesocompost) produced in the absence of worms.

Compost worms do best under moist conditions, but are very sensitive to elevated carbon dioxide levels (Edwards & Bohlen, 1996). Suspending the worm bed to promote aeration through the medium improves both temperature and gas control. The best rations for worms are simple organic carbon compounds, with low levels of ammonia nitrogen. Pre-composting material before feeding to worms reduces the ammonia toxicity, but also reduces the amount of simple organic carbon compounds (Frederickson *et al*, 1997). Using the material directly and if necessary adding clay minerals (eg zeolite) to reduce the ammonium concentration, conserves the organic carbon and avoids double handling (Chan & Griffin, 1988). Feedlot manure has the advantage that much of the ammonia will have volatilised before the manure is collected. Accordingly very little pre-processing of the manure is required for vermicomposting (Mitchell, 1997).

Many claims have been made about the benefits that compost worms confer to vermicompost. These include enhanced mineralisation rates, enhanced microbial activity, the production of plant growth stimulating secretions, and high rates of waste volume reduction (Edwards & Neuhauser, 1988). However in controlled studies comparing the decomposition of farrowing sow manure with and without worms, these properties could not be reproduced (Pittaway, unpublished). Two trials were undertaken consecutively, over 26 (trial 1) and 17 (trial 2) weeks. The duration of the trials was related to the amount of time that it took for the containers used to fill to capacity (about 0.1 m^3). Over the duration of the trials the ration fed to the sows was changed, with the substitution of wheat fines in Trial 1, for sorghum fines in Trial 2. Sorghum protein is very tightly bound in the endosperm of the seed (Rooney & Pflugfelder, 1986). As a consequence, sorghum is less digestible to pigs than wheat. The results suggested that sorghum fines were less digestible to worms. Indeed the substitution of sorghum fines for wheat fines had a greater impact on the concentration of nutrients in the compost than the presence or absence of worms.

Chemical analyses provided by local vermicomposters also indicate that the feed supplied to the worms has a major effect on the total nutrient composition of vermicompost (refer also to Buchanan *et al*, 1988).

Neither was there evidence of microbial stimulation relative to the no-worms control. The worms and no-worm controls were fed on a weekly basis with fresh farrowing sow manure. Manure was withheld for a fortnight at the end of the experiment. Hence the age of organic matter derived from the faeces ranged from 2 weeks to 17 or 26 weeks. The results of radish and sorghum seedling bioassays indicated that phytotoxic compounds actively reduced root growth in slurries produced from both the worm and no-worm composts. This is consistent with the findings of Keeling *et al*, (1994), for unstable organic material. Neither was there any evidence of the initiation of root primordia in cuttings of salt bush treated with a 5:1 water to compost (volume for volume) solution. Accordingly, claims about the properties of vermicompost should be viewed with caution, particularly when the material has been processed with worms for less than 8 weeks.

The biological instability and the low temperature requirements of vermicomposting indicate that the potential for pathogen survival and regrowth is quite high. Some vermicomposters recommend pasteurising or sterilising the raw materials as a critical control point (Edwards, 1995). However there is still ample opportunity for recontamination and regrowth during and

after worm processing. For these reasons, vermicompost should not be used for growing minimally processed fruit and vegetable crops. The inherent variability in the concentration and availability of nutrients in vermicompost also makes the application of the product to meet crop fertiliser requirements difficult. However given the much higher price required to cover the costs of handling, it is highly unlikely that vermicompost will be applied at sufficiently high rates to soil to pose a nutrient pollution risk.

9.1.6 Disposal of animal cadavers

Traditionally the management of animal mortalities (cadavers) at feedlots has been to either bury them, or to transport them off-site for rendering (Skerman, 2000). Given that the incidence of mortality is relatively low, most feedlots continue to bury cadavers. Guidelines in the Feedlot Reference Manual are provided to minimise the possibility of leachate from the cadavers into ground or surface water supplies (Skerman, 2000). Alternatively, feedlots in close proximity to commercial rendering plants can contract the transport of cadavers for recycling. Burning is not recommended, as odour and smoke are generated in the process.

More recently, the adoption of dry composting is being promoted in the intensive livestock industry. Dry composting does not require specialised equipment as with rendering, and avoids the alienation of land associated with burial. Recommendations are provided in the Feedlot Reference Manual for establishing a dry composting facility (Skerman, 2000). A more detailed description of the science behind the procedure is given in the section below.

9.1.6.1 Dry composting animal mortalities

Recently, the absorbent properties of bulking agents used in thermophillic composting have been used to stabilise putrescent wastes such as animal mortalities and the solid waste from abattoirs (Pittaway 2001a, 2001b, and 2001c). The system is an adaptation of the natural decomposition processes of cadavers studied by forensic scientists. Unlike conventional thermophillic composting, the biological organisms being managed are arthropods – mainly highly specialised insects (Payne *et al*, 1968; Shean *et al*, 1993).

Forensic scientists divide the successive ecological steps in cadaver decomposition into four major stages:

- Fresh stage
- Bloated stage
- Active stage, and
- Dry decay stage

The odours most commonly associated with cadavers are produced during the bloated stage. Even in cadavers buried more than 1 m below the soil surface, the odours associated with bloat attract the burrowing activity of highly specialised insects (Payne *et al*, 1968). Nuisance flies and other vermin are not as sensitive in their capacity to detect these odours. In dry composting, sawdust or barley chaff are the bulking materials of choice to reduce odour for vermin control. Sufficient material is placed both above and below the cadavers, to absorb both seepage and odours produced during the first three stages of decomposition.

Water is not added to the pile, as commonly water constitutes more than 70% of the fresh weight of cadavers and other putrescent material. If the cadaver becomes waterlogged, the fat surrounding the body can transform into adipocere, which is extremely difficult to degrade

(Corry, 1978). Arthropods are adapted to existence in relatively dry environments, and are capable of mechanical entry into the cadavers. Therefore water is not limiting for decomposition, and indeed the sawdust or chaff should remain as dry as possible to maximise the odour and seepage absorption properties.

Unfortunately, published information in the literature has confused the natural decomposition processes of cadavers with the microbiological requirements for conventional composting (eg Fulhage, 1997; Imbeah, 1998). Practices such as ensuring a carbon to nitrogen ratio of 25:1 or 30:1, and water contents of 50 - 60% are unnecessary and counterproductive, increasing the risks of odour generation, seepage and adipocere formation, actively slowing down decomposition. Keeping the sawdust or chaff dry maximises odour control and selective insect activity, until the cadavers have been reduced to dry hide and bone. At this stage the putrescent material has become exhausted and the insects depart, seeking out fresher cadavers.

Maintaining a dry compost also enhances the physical degradation of bone (Nicholson, 1996, 1998). In the Agwise Demonstration projects, bones that had decomposed to the dry-decay stage readily fractured when passed through a domestic shredding machine, even the leg bones of cattle (Pittaway, 2001c). Shredded dry-decay remains could be used as a mulch for horticultural purposes, or could be used as a bulking agent for conventional thermophillic composting (Pittaway, 2001b).

Experience with country meat processors and poultry farmers indicates that 6 to 8 weeks after the burial of the last cadaver or animal waste, the putrescent material has been processed by the arthropods, with the remains sufficiently dry to produce very little odour (Pittaway 2001a, b and c). At this stage emptying the compost bay is relatively cost-effective, with minimal risk of odour or seepage during transport. In contrast, burial alienates the land for many years, and the risks of vermin activity, odour, and the contamination of surface or ground water are much greater.

There is the possibility that clostridial bacteria may survive in the dry-decay remains. Poultry cadavers have been associated with the outbreak of botulism in cattle fed poultry litter (Hogg *et al*, 1990). Accordingly, the use of shredded dry-decay remains as a mulch in horticulture should be restricted to crops that are substantially processed or heated prior to eating. They should not be applied to raw food crops (ie those eaten after minimal processing).

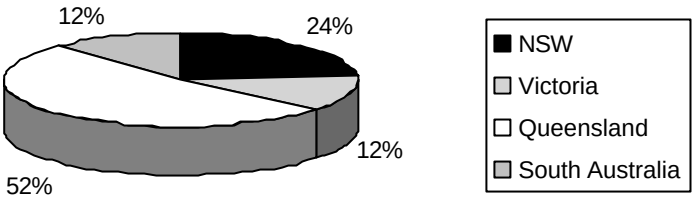
Alternatively, adding the dry decay remains as a bulking agent in conventional thermophillic composting should reduce any hazards associated with potentially pathogenic microbes (refer to the composting section of this report).

9.2 ACTUAL PRACTICES

9.2.1 Feedlot Survey

A survey (Appendix 2) was sent to 65 feedlots to determine their waste management and waste product practices.

FIGURE 5: SURVEY RESPONSES (N=25)

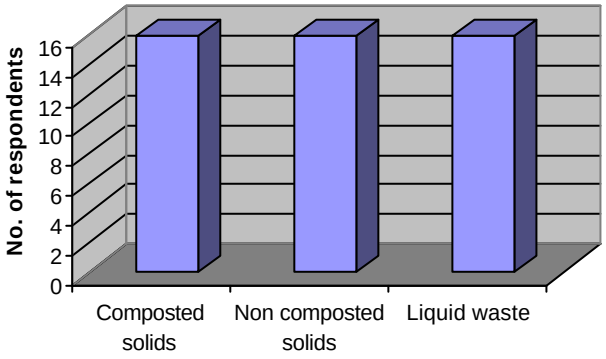


Twenty-seven replies were received, two of which were returns (no longer operated a feedlot). Twenty-four percent of the valid replies were from New South Wales, 12% from Victoria, 52% from Queensland, 12% from South Australia and 0% from Western Australia (Figure 6).

9.2.1.1 Products

Respondents indicated what waste products they produced as part of their operation.

FIGURE 6: WASTE PRODUCTS PRODUCED (N=25)



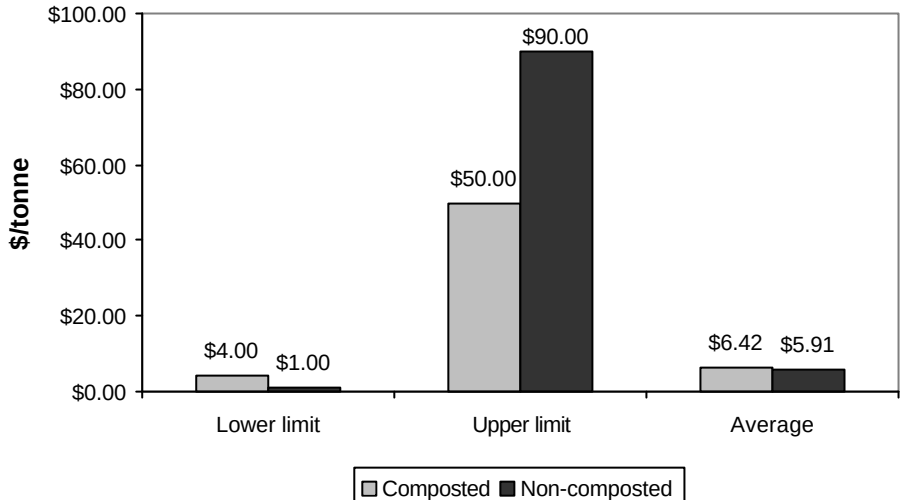
Composted solids were produced by 64% (16/25) of respondents. Of those producing compost, on average 10,824 tonnes of compost were produced per feedlot per year, ranging from 20 t/annum to 60,000 t/annum.

Non composted solids were produced by 64% (16/25) of feedlots (six feedlots produced both non-composted solids and composted solids). Of those producing non-composted solids, on average 13,756 tonnes of non-composted solids were produced per feedlot per year, ranging from 100 t/annum to 60,000 t/annum.

Liquid waste used for irrigation was produced by 64% (16/25) of feedlots. The remainder of feedlots used evaporative ponds or did not state their use of liquid waste. The amount of liquid waste produced ranged from 1.5 ML to 400ML per annum averaging 80 ML per feedlot.

No feedlots directly produced any other waste products such as vermicasts or pelletised manure.

FIGURE 7: VALUE OF SOLID WASTE PRODUCTS



Composted solids on average sold for 51 cents more per tonne than non-composted solids (Figure 7). The highest price achieved for any solid was $90 per tonne for non-composted solids. Liquid waste was only assigned a value by three feedlots (up to $500 per ML).

9.2.1.2 Use of Waste

FIGURE 8: USE OF COMPOSTED PRODUCT (N=16)

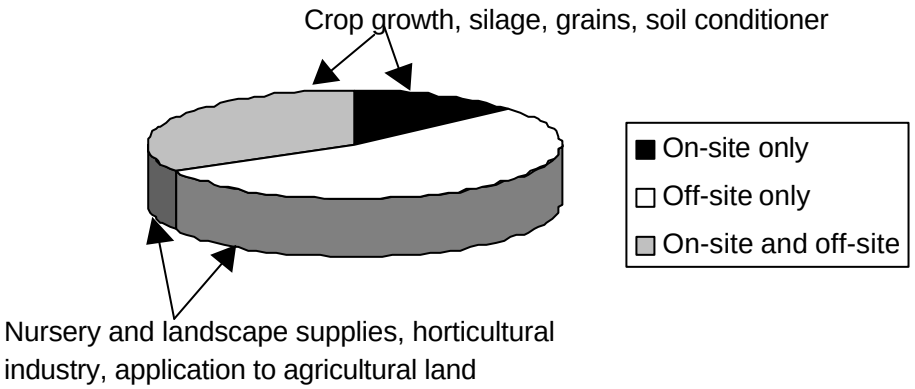
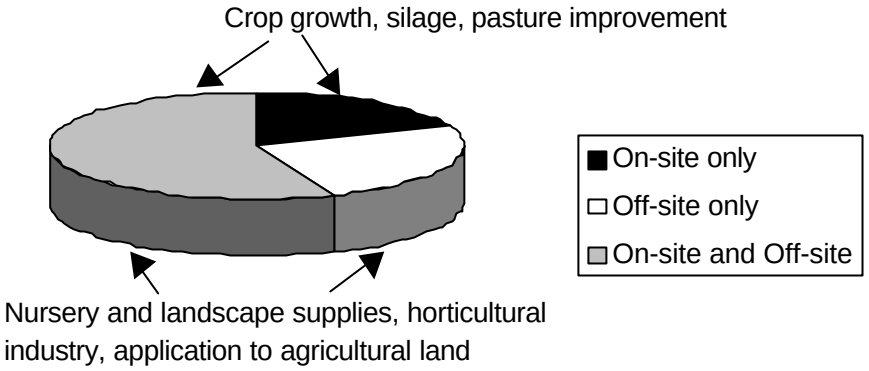


Figure 8 shows that only a small proportion of feedlots producing composted solids used the product exclusively on-site (13%). Composted materials were more often sold off-site to nursery and landscape supplies, horticultural industry (including vineyards and orchards) and to customers applying them to agricultural lands. On-site usage for composted solids included crop growth, silage, grains and soil conditioner.

FIGURE 9: USE OF NON-COMPOSTED PRODUCT (N=16)



Feedlots producing non-composted solids generally used them both on-site and sold the product off site.

All feedlots producing liquid effluent used the product on-site for irrigation of crops. One feedlot also used liquid for dust control on internal roadways. Some feedlots indicated the method of irrigation which was generally diluted, then applied by flood or travelling irrigator.

9.2.1.3 Waste Treatment Methods

Non-composted solids

- Most feedlots producing non-composted solids stockpiled the product prior to use (not turned) for 15 to 365 days (median 100 days). Other feedlots also utilised waste direct from the pen or windrowed prior to use for 10 - 180 days (median 55 days).
- Several feedlots utilised all three methods (stockpiled prior to use, used direct from pen, or windrowed prior to use).
- Eleven feedlots nominated guidelines they used or followed for non-composted wastes. The most commonly referred to guideline was the Environmental Protection Agency (EPA) guidelines; the National Beef Cattle Feedlot Environmental Code of Practice; the feedlots' own environmental management plan (EMP) or licence conditions; and end user supplier programs.
- Eight feedlots tested for nutrient balance; one also tested for heavy metals and weed seed; one indicated that testing is undertaken by the customer. The remainder of feedlots did not test or did not specify.

Composted solids

- Fifteen of the 16 feedlots that composted solids provided information on their composting system.
- The length of composting ranged from 10 to 400 days (median 110 days).
- Ten feedlots windrowed, two feedlots stockpiled, one produced green compost and two did not nominate the method of retaining the waste.
- Watering and turning details varied by individual feedlot with 13 feedlots detailing their method. Four turned and watered, seven turned only and two neither watered nor turned.
- Turning of the compost responses included "turned once", "twice turned", "occasionally turned", "regularly turned", "turned once per month" and "turned once per week".
- Only one feedlot specified a moisture and temperature ratio in their watering and turning method.

- Guidelines followed for composted product included Queensland DPI; EPA; National Feedlot Accreditation Scheme; EMP; AS 4454-1999; NASAA Guidelines; ISO program; National Beef Cattle Feedlot Environmental Code of Practice; and feedlot licence.
- Eleven feedlots tested the compost for nutrient balance; four tested for weed seeds; two tested for *E. coli* and Salmonella (one of which also tested for coliforms and legionella); two tested for heavy metals; one tested for organochlorine and organophosphate; two feedlots nominated that their customers do testing; and one feedlot did no tests.

9.2.1.4 Supply and Demand

FIGURE 10: DEMAND FOR FEEDLOT WASTE PRODUCT

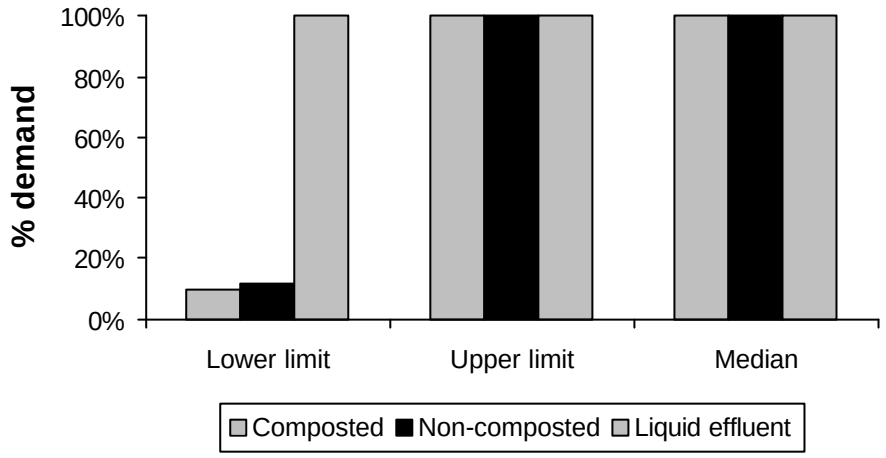


Figure 10 shows the current demand for all feedlot waste products is high. Only two feedlots could not move all the non-composted they wanted and another two could not move all the composted waste they wanted to move.

9.2.1.5 Supplier Requirements

- Supplier requirements for non-composted solids were only provided to 27% of the feedlots producing them. These requirements specified nutrient analysis, “free of stones” and “older than 12 months”.
- Supplier requirements for composted solids were provided to most feedlots producing them. Requirements included “free of foreign matter”, “6 months old and be nutrient and weed tested”, “nutrient analysis” and “if required NASAA standards and EPA guidelines”.

9.2.1.6 Skills Required for Waste Treatment

Most feedlots nominated that on the job training was required for treatment of waste. Five feedlots employed consultants for waste advice. Two feedlots required certificate based training, while two required no qualification.

9.2.1.7 Compost Dead Cattle

Forty-six percent of respondents composted dead cattle. The number of days composted ranged from 60 to 500 days.

9.2.1.8 Wet Weather Storage of Effluent

Eighty-eight percent of feedlots had a site available for wet weather storage of effluent used for irrigation (ie another site (eg tank/pond) to hold liquid effluent in the event of heavy rains or over capacity in the effluent pond).

9.2.1.9 Market Concerns

Five feedlots responded that markets had expressed concern regarding the possible health effects of feedlot waste products. Replies included:

".. the feedlot is developing an information handout for customers to address concerns"

"Yes in relation to *E. coli,* Salmonella and Listeria."

"Almond producers and vegetable growers (have expressed concern)."

"Yes, but it hasn't prevented anyone from using it."

"Some have asked about HGPs and feeding of animal by-products. Q-fever also raised."

9.2.1.10 Transport issue

The cost of waste transport was an issue for 54% of respondents. Comments recorded included:

"Cost is significant - nature of finished product dictates economics of freight as is bulky per unit of NPK, eg compared with chemical fertilisers"

"Important, especially in trying to get a decent price for compost"

"Very significant - cost of transport reduces no of customers to only customers within 20 km radius. Might look at back loading grain trucking but trucks must be cleaned."

"Freight is a large cost to distant markets compared to the cost of the product."

"Transport is a large cost, however is paid for by the purchaser of the manure."

"Very significant. Value in raw manure makes it difficult to justify the cost of freight and the amount of manure required/ha vs fertilisers"

"Low issue because of close proximity to end market"
"No issue other than end users always use freight as a tool to lower per tonne/cubic metre rate"

"Not an issue if marketing to high return producing areas eg light soil type grape, almond and vegetable growing areas."

"Not important. In this area demand outstrips production resulting in increasing prices."

9.2.1.11 Barriers/Limitations

Respondents were asked what other barriers or limitations to marketing waste products exist. Comments are provided below (categorised).

Cost issues
- Cost of spreading and handling manure. Being able to sell the benefits of a soil conditioner to the public
- Basically what the market is willing to pay versus the cost of production of value added waste products
- High level of capital investment required to process solids
- Transport cost.

Quality problems
- Moisture content for nursery users
- Pressure to screen and compost manure
- Quality (ie degree of composting - stone free etc)
- Quality, nutrient balance and the ability to further compost
- Some problem with weed seeds - not really a barrier though
- The inconsistent product, and volume required are the biggest barriers.

Consumer awareness
- Weather, scientific support, long term benefits (or disadvantages) as yet unknown.
- Poor consumer awareness, financial value and nutrient quality of product
- Ignorance in relation to perceived weed infestation. Seen as fertiliser rather than soil conditioner and therefore unfairly costed as fertiliser.

Communication
- Farmers need more information on waste utilisation and the benefits to their production systems

9.2.1.12 R&D Requirements

Respondents were asked to identify what R&D in waste treatment or waste product development they think was required. Comments from respondents are given below (categorised).

Product development
- "Perhaps concentrating on product - pelleting?"
- "Reducing the testing required by regulatory bodies."

- "Methods of improving nutrient availability and reduce weed seed contamination."
- "More research into composting and how best to market."
- "Waste to energy possibilities."
- "Weed seed destroyed in composting - can use herbicides post spreading to better address need."
- "Methods of screening to achieve a better product (ie simple, cheap, cost effective design to screen composted feedlot manure to keep stones off paddock)."
- "Method of composting to allow cheap but effective stock pile design and watering system."
- "What yields on crops for different application (tonnes/acre)."
- "Research into quantifying capacity of effluent waste to be used in dust control on roads and pens within the feedlot confines."
- "Research in Pad design/composition at heavy traffic area ie. water through concrete aprons, fence lines very important during winter."

Risk/Health
- "What you are doing now"
- "To determine human health risks."
- "Air borne risks."
- "Research into any possible harmful effects from composting dead animals. Possibly guidelines specific for large carcase composting."
- "Safety of manure/compost usage to the public. Obligations to feedlot of people stockpiling product off site. Use of composted carcases (safety etc)."

Market development and Education
- "Cost benefit analysis of all methods of disposal and value of composted and liquid waste."
- "Market opportunity and value for resale - ie. (i) areas of disposal eg vineyard, (ii) what value is it worth to them and what can they afford to pay."
- "Better markets."
- "Composting education would be fantastic."
- "Long term advantages/disadvantages of manure and effluent use."
- "Enhancing and making aware the financial and nutrient benefits of product."

9.2.1.13 Additional Comments

- "Because of high costs of fertilisers the use of feedlot waste is an economic advantage."
- "Survey difficult to complete because feedlot is relatively new."
- "The company is working into the viability of irrigating liquid waste onto pasture lands."
- "Composting is a very viable option but good information is hard to find. Carcase composting is excellent but is it able to be utilised?"

9.2.2 Assessment of Actual Practices

Based on an assessment of the feedlot surveys, current feedlot waste practices that have the potential to impact on human and/or animal health were identified.

- The end use of waste products was of concern in many instances as follows:
  - Use of non-composted solids or liquid untreated waste as fertiliser for crops or silage fed back to animals in the feedlot. While the path of transfer of zoonotic diseases can

not be fully verified because of lack of data, this practice should be treated with caution.
  - Use of non-composted solids or liquid untreated waste as fertiliser for crops sold off the property for animal or human feed that receives minimal processing.
  - Use of effluent used for irrigation on pastures which may be subsequently grazed. Suitable withholding periods are required before pastures can be safely grazed.
  - Use of non-composted feedlot solids by growers of fruit and vegetables, particularly the products which can be eaten uncooked and/or grown in or close to the ground. Feedlots should not sell waste product that is likely to be used in these applications.

- Method of composting. Composted product could not be considered as being produced from feedlots that only composted for short periods (eg 10 days) and neither watered or turned their compost piles. Feedlotters may benefit from receipt of suitable material that clearly identifies the correct methods for composting, the benefits of following these methods and the possible consequences of not following correct composting techniques.

- The safety and stability of composted product was not demonstrated by most feedlots. Only two feedlots tested for product safety (pathogens and heavy metals) and only one specified a time-temperature monitoring regime. A monitoring program for composted product must be established by feedlots producing composted product.

- Very few end users imposed specifications on waste products sourced from feedlots. Of those that did, the specifications did not related to scientific health or risk matters (eg free of foreign matter, nutrient analysis). One supplier specified the composted material be six months old however it was not certain this was due to any health or other risk factor and based on our literature review findings, this would not provide a guarantee of safety. Supplier education is a critical factor in assisting the feedlot industry to reduce risk.

- Few risk reduction strategies were nominated by feedlots, but the NFAS was commonly referred to. An opportunity may exist for the NFAS to provide the framework in which to incorporate waste product management guidelines identified from this project.

Feedlot operators consider that cost, quality problems (eg consistency, weed seeds, stones) and lack of customer awareness to the benefits of using feedlot waste are barriers to investment in adequate waste treatment and utilisation processes. Costs include the high level of capital investment, the cost of handling the manure, transport costs and the relative value of the end product. To further minimise risk, feedlots should consider supplying the product to a specialist treatment party for further processing and on-selling. Companies such as Envirorganics (Queensland) are offering this service to feedlots.

Customer awareness of the value of feedlot waste products was also limited and end users were likely to consider it as a soil conditioner rather than a fertiliser. As a result, they unfairly costed the product. While this is not a “health” issue, it appears likely to be a significant barrier in establishing effective waste treatment methods because optimum returns for waste product are not available (or not perceived to be available).

In summary, without feedlots adopting risk management protocols, the potential for human and animal health problems as a result of feedlot waste management and disposal practices appear significant. Existing risks as detailed in Table 8 (Risk Assessment) would apply to most feedlots currently operating. There is an urgent need to supply feedlots with information

which will minimise these risks by assisting them to implement risk management protocols within their operations.

10. PROGRAMS, CODES, STANDARDS AND LEGISLATION

Regulations, codes, legislation and other requirements for production of waste products should be based on a scientific assessment of the risks to human health. "Over" regulation can be an issue in terms of compliance costs for feedlots, making the decision to produce marketable products difficult. On the other hand, regulation which does not sufficiently consider human health or animal health issues can potentially put the industry at risk if an incident does occur. It is therefore vitally important that an overall risk reduction program, whether based on legislation or other programs is undertaken by individual feedlots.

In this section of the report, the research team has considered all applicable guidelines, codes, standards and legislation. The Australian Standard for composts, soil conditioners and mulches and the AFFA guidelines for on-farm food safety have been considered in detail (9.1 and 9.2). Other relevant State legislation and codes are covered in 9.3.

10.1 AS 4454 - 1999 COMPOST, SOIL CONDITIONERS AND MULCHES

The Australian Standard for composts, soil conditioners and mulches (AS4454 – 1999) applies to "organic products and mixtures of organic products that have been treated by pasteurising or composting procedures as defined by this Standard. … shredded green waste … and vermicasts … that have not been subjected to either a pasteurisation or composting procedure are specifically excluded from this Standard, mainly because they have a high probability of containing weed and plant pathogen propagules." This standard would not apply to those feedlots that dispose of their manure unprocessed via land application.

The acceptance of the AS4454 has been steadily growing since it's introduction in 1997 (Wilkinson *et al*, 2001).

The Standard states that manures that have been composted or pasteurised are required to:

- have undergone composting for a period of at least six weeks.
- have a minimum of three turns with the internal temperature reaching a minimum of 55°C or three consecutive days before each turn.
- meet certain physical and chemical criteria which vary depending on the process used (compost or pasteurisation) and the category of product (soil conditioner, fine mulch or mulch).
- be free of plant propagules.
- supply certain information to the purchaser of the product, including supplier details, product classification, suitability for phosphorous sensitive plants, a health warning label and a hazardous information label. For bagged product, the information is to be marked on the package and for bulk product, an information sheet is to be provided.

Potential issues for the feedlot industry resulting from the pathogen and chemical contaminant requirements within AS4454-1999 follow.

10.1.1 Issue 1: Compliance to national health standards and costs

AS4454 has a general requirement for compliance with national health standards. Under this requirement, "*all materials shall fully comply with the chemical contaminant and organic contaminant provisions of the current version of the State or Federal guidelines for use and disposal of biosolid products that are for unrestricted use, whichever is the more stringent.*"

The federal biosolids management guidelines is published by the Agricultural Resource Management Council of Australia and New Zealand. Relevant state guidelines have been published in New South Wales (NSW EPA, 1997), South Australia (SA EPA, 1997) and Tasmania (Tas DPIWE, 1999). A draft guideline has been released in Victoria (VEPA, 2000) and guidelines are currently under development in Western Australia and Queensland. Most of these guidelines classify products based on contaminant levels and stabilisation processing, with similar classification criteria used in the various guidelines. Stabilisation grading classification criteria are based on reduction of both pathogens and vector attraction (ie attraction of flies and vermin). An example of pathogen reduction criteria is listed in Table 11. Contaminant criteria for published guidelines are shown in Table 12.

TABLE 11 PATHOGEN REDUCTION CRITERIA FOR UNRESTRICTED USE PRODUCTS – NSW BIOSOLIDS GUIDELINES

Parameter	Standard
Stabilisation Microbiological Standards	
E. coli	<100 MPN per gram (dry weight)
Faecal coliforms	<1,000 MPN per gram (dry weight)
Salmonella sp.	Not detected/50 grams of final product (dry weight)

MPN = most probable number

TABLE 12 CONTAMINANT CRITERIA FOR UNRESTRICTED USE PRODUCTS – AUSTRALIAN BIOSOLIDS GUIDELINES

Contaminant (mg/kg)	National	NSW	Victoria	SA	Tasmania
Arsenic	20	20	20	20	20
Cadmium	1	1	1	3	3
Chromium	100-400	100	400	-	100
Copper	100	100	100	200	100
Lead	150-300	150	300	200	150
Mercury	1	1	1	1	1
Nickel	60	60	60	60	60
Selenium	3	5	3	-	5
Zinc	200	200	200	250	200
DDT/DDD/DDE	0.5	0.5	0.5	-	0.5
Dieldrin & other organochlorine pesticides	0.02-0.05	0.02	0.05	-	0.2
Polychlorinated byphenyls (PCBs)	0.05-0.3	ND (DL=0.2)	0.05	-	0.3

*DL: Detection Limit

As detailed in Section 6, limited information is available regarding contaminant concentrations in manure. Testing for heavy metals or pathogens has not been widely undertaken within the feedlot industry. Information that is available suggests that the manure from most feedlots would be within the levels specified for unrestricted use. However, zinc concentrations at some feedlots may be higher than threshold levels. Measured levels of DDT, organochlorides and PCBs in feedlot manure have not been reported, but most feedlot manure would not be expected to exceed these guidelines.

A major potential issue with compliance of these guidelines is the costs associated with assessing products. This issue has the potential to be addressed in Queensland and Victoria, where animal manure management has been considered specifically in relevant guidelines.

Biosolids management guidelines outline sampling and testing requirements for both contaminants and stabilisation as an ongoing management procedure. These requirements have been developed specifically for biosolids to address issues of variability in product entering sewerage treatment plants. Because feedlot manure characteristics are relatively consistent the testing requirements developed for biosolids would represent an unnecessary cost for feedlot manure processors wishing to access unrestricted markets for their product.

The AS4454 standard does acknowledge that chemical contamination (including heavy metals) is primarily a concern where biosolids are used in a product. It is recommended that for products not using biosolids, routine testing for chemical contaminants can be less frequent than for biosolids-based products. Where ingredients are changed, the testing process would need to restart. Even so, chemical contamination in feedlot waste product is likely to be acceptable, and if demonstrated, should not be a requirement for the industry.

No guidance is provided in AS4454-1999 regarding managing high levels of contaminants. Recommendations for minimising pathogen survival are provided within the composting best practice guidelines included in the standard. These guidelines are directed at four commonly used composting systems – turned pile, aerated static pile, windrow and in-vessel.

10.1.2 Issue 2: Regrowth of Pathogens

Some food safety guidelines refer to the regrowth potential of zoonotic pathogens in manures and composts. However the conditions favouring regrowth are not necessarily indicated, and tests for measuring regrowth are not included. AS4454 makes no reference to the problems associated with pathogen regrowth.

Pathogen regrowth is most likely to occur in biologically unstable composts (Soares *et al*, 1995). By definition, biologically unstable composts contain sufficient readily available organic carbon compounds to enhance microbial growth. Under warm, anaerobic conditions, similar to those encountered in the gut of animals, potentially pathogenic coliform bacteria could and do regrow.

The six week composting period referred to in AS4454 gives no indication of the state of maturity of the compost. The time required for composting is a function of the management of moisture and aeration within the windrow, and the chemical and biological composition of the raw materials used (Gagnon & Simard 1999). If insufficient aeration or moisture is provided, or if the raw materials are timber-based, the compost is highly unlikely to reach biological maturity within the specified 6 weeks. On rewetting, the potential for pathogen regrowth may be substantial (Soares *et al*, 1995).

AS4454 does include a method for testing the self-heating properties of a compost. Self-heating is associated with the flush of microbial growth associated with re-wetting a biologically unstable compost. If a correlation between the results of the self-heating test and the pathogen regrowth test of Soares *et al*, (1995) can be established, then the self-heating test could be used to determine the regrowth potential of the compost. Mature, biologically stable composts are highly unlikely to support pathogen regrowth, and therefore represent the safest manure-based material for use on minimally processed fruit and vegetable crops.

10.2 AFFA GUIDELINES FOR ON-FARM FOOD SAFETY FOR FRESH PRODUCE

In July 2001, AFFA produced a guideline food safety document for fresh produce. Given that a large proportion of feedlots supply non-composted and composted solids to the horticultural industry, the AFFA guideline has significance for marketing of feedlot waste products.

The guideline states that microbial contamination of fresh produce can be caused by the use of organic animal products, either directly by contact with the product or indirectly through contact with contaminated soil or water. The guide recommends a number of practices that minimise the risk of microbial contamination including composting (defined as having a treatment period of 6 weeks) or ageing (6 months).

For organically grown products, the guideline recommends using treated organic fertiliser to minimise microbe levels. An example provided is pelletised manure. However, this is contrary to our desk-top research which has indicated that some pelletised manure poses a definite risk.

The AFFA guideline recommends that only properly composted manures should be used for side-dressings, and that the composts should contain less than 100 *E. coli* per gram. However unless the degree of compost maturity can be established, the potential exists for pathogen regrowth in a biologically unstable (immature) compost initially containing less than 100 *E. coli* per gram. A decision tree for assessing the risk of microbial contamination from fertilisers and soil additives is shown in Figure 11.

The AFFA guideline also recommends that side-dressing with a compost should not be applied within 2 weeks of harvest, and direct contamination of the plants should be avoided by not applying the compost over the top of the plants.

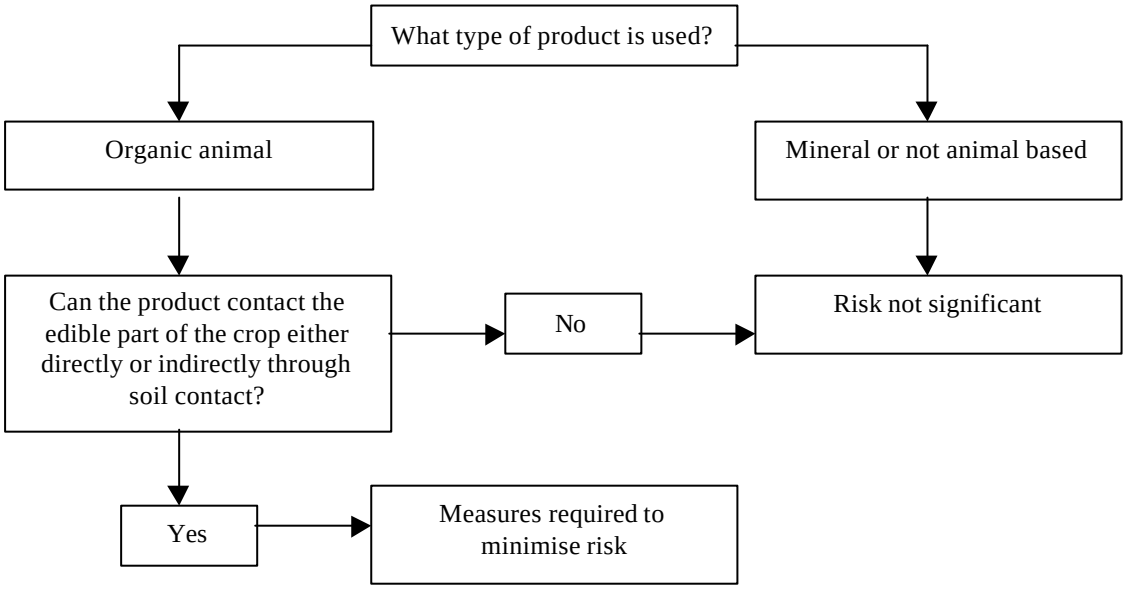
Provided that a feedlot protocol includes temperature and moisture monitoring and composting to the point of biological stability, the AFFA guidelines, that are otherwise very comprehensive, will ensure that the risks of pathogen transmission from raw manure used in compost to minimally processed fruit or vegetable crop is minimal. For raw food crops that are not in direct contact with the soil, or for food crops undergoing a higher degree of processing prior to ingestion, such stringent guidelines on the maturity and quality of composts may not be warranted.

Water used for irrigation is also detailed in the AFFA guidelines. Any irrigation water at risk of faecal contamination requires testing. The recommended test is for faecal coliforms, with an upper limit specified at less than 1000 faecal coliforms per 100 ml.

Therefore, water from feedlot holding ponds, non-composted materials and improperly composted materials should not be marketed by the feedlot industry to growers who might apply these products to crops marketed as minimally processed produce. In addition, adequate buffer distances should be implemented for the irrigation of effluent close to watercourses and groundwater bores and between areas that might be used for the production of food that is minimally processed prior to final consumption.

The guideline appears to discourage the use of biosolids produced during the biological treatment of human sewage, therefore the market potential for the feedlot industry appears quite significant providing risk reduction techniques can be demonstrated.

FIGURE 11: DECISION TREE FOR GROWERS



10.3 OTHER LEGISLATION, CODES OF PRACTICE AND STANDARDS

The range of documents that have been included in this review include:

- Acts (and associated regulations)
- Guidelines
- Codes of Practice
- Australian Standards

The areas in which legislation and codes could have an effect on the transfer of contaminants include:

- Planning consents (through conditions of approval)
- Environmental protection
- Veterinary health
- Public and occupational health

10.3.1 Planning Legislation and Codes

The planning process with its associated legislation and guidelines is well established in most Australian states. This follows the controversy that followed feedlot development in the early 1990's. Each state adapted or amended legislation to cover the planning process for feedlots at a state and local government level. National feedlot guidelines were developed and each state developed their own guidelines.

The acts and guidelines used in the planning process for feedlots aim to ensure that a feedlot will be sited, designed and managed in a manner that will be environmental sustainable and acceptable to the general public. At the time when the guidelines were developed, the key issues were community amenity (odour, dust, flies) and nutrient management (nitrogen, phosphorus, salt). At that time, heavy metals and pathogens were not recognised as issues for the feedlot industry.

10.3.1.1 National Feedlot Guidelines

The National Guidelines for Beef Cattle Feedlots in Australia (SCARM 1997) is considered to be the principle reference document for the establishment and operation of cattle feedlots in all states of Australia. These Guidelines arose from concerns within the feedlot industry that the lack of uniformity of state regulations relating to the establishment and operation of feedlots in Australia was hindering the development of the industry. These guidelines cover environmental impact and animal welfare issues.

Since then the NFAS has been introduced. The NFAS is intended to complement the Guidelines and is based on compliance to three Codes of Practice: The National Beef Cattle Feedlot Environmental Code of Practice, the Australian Model Code of Practice for the Welfare of Animals – Cattle, and the Australian Veterinary Associations Code of Practice for the Safe Use of Veterinary Medicines on Farms.

With respect to the transfer of contaminants, SCARM (1997) makes no explicit reference to heavy metals or pathogens but many of the environmental controls described in the guidelines should minimise the transfer of these contaminants.

10.3.1.2 Queensland

In terms of their potential environmental impacts, cattle feedlots and any associated activities are regulated in Queensland under the *Environmental Protection Act 1994* (EP Act). The Department of Primary Industries, (DPI) in particular the Intensive Livestock Environmental Management Services (ILEMS) group based in Toowoomba is the regulatory body responsible for the environmental administration of cattle feedlots and any associated activities. DPI has been devolved authority from the Environmental Protection Authority (EPA) for licensing feedlots.

Cattle feedlotting is described as an Environmentally Relevant Activity (ERA) in Schedule 1 of the *EP Regulation 1998*.

Under the provisions of the EP Act, the DPI's responsibilities include assessing applications for new developments, issuing environmental authorities (with appropriate conditions),

monitoring ongoing operational and environmental performance and investigating complaints regarding feedlot operations.

The development of a new or an expanding cattle feedlot is also subject to legislation under the *Integrated Planning Act 1997* (IPA). New or expanding cattle feedlots are classified as Impact Assessable Developments and are therefore required to apply for Town Planning approval under the Planning Scheme of the particular Shire in which it is to be located. The landowner must make application to the Local Shire Council requesting development approval to authorise the feedlot development on a particular Lot of land.

There are two documents that relate to the cattle feedlot industry in Queensland that have no legislative powers. These documents are intended as 'guidelines' for the feedlot industry and include:

- The Reference Manual for the Establishment and Operation of Beef Feedlots in Queensland
- National Guidelines for Beef Cattle Feedlots in Australia

The Reference Manual (Skerman 2000) was produced under the direction of the Qld Cattle Feedlot Advisory Committee (FLAC). The manual was developed to provide the most up-to-date information available to ensure the environmental sustainability of cattle feedlotting. The manual provides information on manure management, composting, vermi-composting and on-farm manure utilisation.

Like the national guidelines, the reference manual makes little reference to heavy metals or pathogens although a stated objectives of manure stockpiles is to reduce the number of pathogens in manure. The list of parameters for which effluent and manure is to be tested only covers nutrients (N,P,K) and salts.

Although scant reference is made to pathogens and heavy metals, the environmental management recommendations included in the reference manual should ensure that no potential contaminants reach surface or groundwaters.

10.3.1.3 New South Wales

In terms of their potential environmental impacts, cattle feedlots larger than 50 head in New South Wales (NSW) require development consent under the State Environmental Planning Policy (SEPP) No 30 – Cattle Feedlots (Amendment No 1) 1993. Environmental impacts are also regulated under the Clean Water Act 1970 and the Pollution Control Act 1970. The Pollution Control Act includes a list of assessable activities and pollutants, providing the structure for licensing operations that have potential to impact the environment. Feedlots are included in the list of assessable activities, but are listed as having no assessable pollutants.

Feedlot applications for facilities larger than 50 head in NSW require environmental impact documentation and details regarding pollution control measures and effluent disposal methods. The New South Wales Feedlot Manual (NSW Agriculture, 1997) lists guidelines for new developments and expansions that include effluent and manure management. A *thorough assessment of the … chemical characteristics of … manure* is recommended and it is suggested that *soil impacts … such as salt accumulation, nutrient imbalance …should be identified*. The manure management sections do not reference pathogens, heavy metals or other contaminants.

The NSW Feedlot Manual (NSW Agriculture, 1997) includes information regarding hormonal growth promotants (HGPs) and antimicrobials. Information regarding the HGPs is related to the consumption of meat rather than potential effects of contamination in manure or other by-products. For antimicrobials, it is noted that the use of Avoparcin might be linked to potential human health effects, but again potential effects of contamination in manure or other by-products are not mentioned. The section related to animal health mentions chemical residues, but in relation to potential contamination of meat rather than manure or other by-products.

A number of acts are administered by NSW Agriculture that are potentially of relevance to contaminants in feedlot by-products. These include

- Pesticides Act 1999 – lists harm to *non-target animal or non-target plant* but excludes harm that has occurred on *the agricultural farm land … in respect of which the pesticide was used*. The definition of pesticide refers to pesticides or mixtures containing pesticides for direct use for control of pests. There is no reference to the survival of the pesticide in the receiving environment.
- Stock Medicines Act 1979 – deals with the registration and control of stock medicines. This act focuses on protecting human health, but *a likely deleterious effect on the environment* is sufficient reason to refuse or cancel the registration of a medicine.
- Stock (Chemical Residues) Act 1975 – is primarily concerned with protecting human health, but stock can be considered *degraded if they … pose a danger … to the environment*.

These acts are unlikely to impact on the ability to re-use feedlot by-products in their current form.

10.3.1.4 Victoria

In Victoria, all new or expanding feedlots are required to meet the requirements of the "Victorian Code for Cattle Feedlots" (Victoria DAEM, 1995). This code does not specifically mention heavy metals or pathogens. It is recommended that the waste management plan consider nutrients and salt.

Other legislation that may apply includes the:

- Catchment and Land Protection Act 1994 – this act deals primarily with the formation of regional catchment and land protection boards and the control of noxious weeds and pest animals. Protection of soil and water resources is mentioned, but no specific references to particular contaminants.
- Environment Effects Act 1978 – this act applies to works that *could reasonably be considered to … be capable of having a significant effect on the environment*. Where this Act applies, a statement of environmental effects must be prepared prior to commencement of works. No reference is made to particular things that may cause an environmental effect.
- Agricultural and Veterinary Chemicals Act 1996 – this act is primarily to minimise the potential for contamination of meat products by agricultural and veterinary chemicals. No mention is made of contamination of by-products.

These acts are unlikely to impact on the ability to re-use feedlot by-products in their current form.

10.3.1.5 South Australia

Under current South Australian planning legislation, the term "farming" does not include feedlots. Accordingly, feedlots are a change of land use from general farming. This change of use requires planning approval from the planning authority that is generally the local council. As part of the applicant process, a Planning Focus Meeting should be held at which the view of various state government departments can be voiced. To assist in the orderly planning of feedlots, a state feedlot guideline was developed (Anon. 1994).

Like the Queensland guideline, the SA guideline concentrates on odours and nutrient management. However, Section 12 deals with public and environmental health and Section 13 deals with animal health regulations (Livestock Act 1997). No specific recommendations are made in relation to heavy metals or pathogens.

10.3.1.6 Western Australia

In Western Australia, feedlot proposals are initially submitted to the local government. Local government assess the proposal for consistency with local planning policies and will seek advice from the Department of Environmental Protection (DEP) and the Water and Rivers commission (WRC). Depending on the size and location of the proposal, an environmental impact assessment may be required.

A set of guidelines has been prepared in Western Australia (Anon. 2001b). As with other feedlot guidelines, it focuses on nutrient management. There is no mention of heavy metals or pathogens.

10.3.2 Environmental Protection Legislation and Codes

10.3.2.1 Industry Programs

The Australian Lot Feeders Association (ALFA) has a "National Beef Cattle Feedlot Environmental Code of Practice". With respect to the transfer of contaminants, this code makes no explicit reference to heavy metals or pathogens but many of the environmental controls recommended in the code should minimise the transfer of these contaminants.

10.3.2.2 Australian Standards

AS 4454 is covered in Section 9.1 of this report.

10.3.2.3 Queensland

The Queensland EPA has commenced development of a guideline for solid organic by-products management. This guideline is to apply to biosolids and animal manures, including feedlot manure. It will be based on the NSW biosolids management guidelines, with alterations to ensure that beneficial use of by-products is encouraged in all industries covered by the guidelines. Manure quality requirements to meet environmental and food safety levels for different cropping systems are likely to be included.

The results of this project will provide the feedlot industry with a valuable opportunity to provide a detailed submission during the development of the Queensland guidelines. This submission should include

- technical information regarding industry benchmarks for pathogens, heavy metals and other contaminants for different manure products (eg raw manure, composted manure, pelleted manure).
- information regarding the ability of these contaminants to survive standard procedures and any processing undertaken.
- information regarding the risk of transfer for the different contaminants.
- processing and application costs for different products.
- the value of the various final products.

10.3.2.4 Victoria

Environment protection (Scheduled Premises and Exemptions) Regulations 1996 – Section 2 is of relevance to the feedlot industry. An intensive animal industry is defined as being premises upon which are situated piggeries or cattle feedlots and the like, where more than 5,000 animals are confined for the purposes of agricultural production. Premises discharging or depositing waste solely to land are exempt from licensing.

The Victorian Department of Natural Resources and Environment (DNRE) are currently developing a guideline for manure management. This guideline is likely to be similar in nature to biosolids management guidelines, with alterations to ensure it is relevant to agricultural industries. Specifically, manure quality requirements to meet environmental and food safety levels for different cropping systems may be included.

10.3.2.5 South Australia

Under the Environment Protection Act 1993 - SCHEDULE 1 Prescribed Activities of Environmental Significance, a feedlot is covered under the section of Animal Husbandry, Aquaculture and Other Activities. Cattle Feedlots are defined as carrying on an operation for holding in a confined yard or area and feeding principally by mechanical means or by hand-
(a) not less than an average of 500 cattle per day over any period of 12 months; or
(b) where the yard or area is situated in a water protection area (as defined for the purposes of the Water Resources Act 1990)-not less than an average of 200 cattle per day over any period of 12 months,

10.3.2.6 Western Australia

The *Environmental Protection Act* 1986 is the primary legislation for the protection of the environment and control of pollution in Western Australia. The necessity for Works Approval, Licence or Registration is determined by the size of the feedlot and its distance from a watercourse. The *Water and Rivers Commission Act 1995* has a number of subsidiary acts and by-laws to protect water resources and these may influence the location and operation of feedlots. Protection of public drinking water sources is a key issue.

10.3.3 Veterinary Health Legislation and Codes

The Australian Veterinary Association's *Code of Practice for the safe use of veterinary medicines on farms* is primarily aimed at minimising potential public harm through contamination of end product. The document states that "the effect of the drugs and

chemicals on target and non-target species and the environment" are taken into account by standard approval systems. Recommendations are made to follow manufacturers or veterinarian's instructions to minimise the risk of harm to the environment.

10.3.4 Public and Occupational Health Legislation and Codes

A number of food industries are now forming their own codes of practice for the application of organic material to food crops. These codes are largely risk-based, with most based on HACCP principles. The AFFA guidelines outlined in Section 9.2 are an example. Current recommendations in other codes for using products that may be contaminated include

- use potentially contaminated product only for crops that are significantly processed after harvesting;
- avoid application of potentially contaminated products close to harvest and avoid contact between harvested portions of plant and potentially contaminated product;
- avoid planting food crops for extended periods (3-18 months depending on particular conditions) in areas where potentially contaminated products have been applied.

Freshcare is the national on-farm quality and food safety management program for growers of fresh produce. The safe use of fertilisers and soil additives is provided in Section F4 of the code and generally covers the same requirements as the AFFA guidelines.

The Australian pulse industry produced a Code of Hygiene Practice for Oilseeds, Pulses and Legumes (AQIS 1989, currently under review). Within the Code emphasis is placed on improving hygiene on-farm during the growing, harvesting, storage and transportation to protect the product from microbial contamination of human, animal, domestic, industrial or agricultural waste origin. Particular care is requested to prevent the cross-contamination of equipment with animal activity (birds and rodents), stockfeed or other animal products including meat meal. These guidelines would preclude the use of raw animal manures for crop production. Pulse Australia also compiles the Pulse Standards, which are then published by the National Agricultural Commodities Marketing Association Inc. (NACMA) as part of its Agricultural Commodities Standards Manual.

The Pulse industry has two quality assurance programs of relevance to feedlot waste management - Grain Care and Great Grain which both put the onus on the grower to demonstrate safety.

The National Association for Sustainable Agriculture in Australia (NASAA 1998) has established upper limits for heavy metal contamination in both the soil, and also for fertilisers and soil conditioners to be added to the soil. For zinc and copper, the soil limit is 150 mg/kg and 50 mg/kg, the fertiliser limit is 1,000 mg/kg and 400 mg/kg, and for soil conditioners the limit is 1.00 kg/tonne and 0.400 kg/tonne respectively. Most feedlot by-products are likely to conform to these standards.

10.3.4.1 Australian Standards

AS4454 – 1999 information is contained in Section 9.1

10.3.4.2 Biosolids Management Guidelines

Covered in Section 9.1

10.3.4.3 HACCP

HACCP is now a commonly used process to establish and minimise risk areas and could be used as a tool for complying with various guidelines. A HACCP based program for the feedlot industry would be based on:

- a sampling and testing regime for characteristics that are consistently found within feedlot manure (eg pathogens), ie development of critical limits and their subsequent monitoring.
- minimisation strategies for risks that can readily be reduced.
- operational changes that may introduce a change in the characteristics of the manure (eg changes to diet formulation increasing the content of metals in the manure).
- establishment of a management plan that incorporates the above processes.

10.3.4.4 Queensland and Victoria

The public health and occupational health codes of relevance are covered in environmental protection legislation and codes (refer 9.3.2.3 and 9.3.2.4.)

10.3.4.5 South Australia

The Public and Environmental Health Act (1987) and regulations provide for the local authority (councils) to deal with environmental nuisance / insanitary conditions including:

- premises giving rise to a health risk
- risk of infestation by rodents and other pests
- offence to any land owner in the vicinity
- offensive odours / materials emitted from premises
- insanitary conditions
- discharge of waste into public or another private property
- inadequate facilities for sanitation
- protection of water supplies
- disposal of dead animals.

Administration of the act in local government areas is by local councils and in non-local government areas, by the South Australian Health Commission.

10.4 END USERS

Discussions were held with a number of end users regarding their concerns with feedlot waste products.

Pulse Australia requires growers to demonstrate that animal products are not used in such a way as to contaminate crops. For example, low harvested products are likely to be at greater risk than high harvested techniques and application of animal waste would not be recommended. The grower needs to demonstrate risk reduction strategies in order to comply.

Other major end users are less concerned. Woolworths and Coles were contacted as two major buyers of horticultural product could be fertilised with feedlot waste. Woolworths, via the Woolworths Vendor Quality Management System have not mandated specific uses of composted material. Rather they rely on the outcome of safe food. This is assessed through the HACCP process and must be demonstrated to a qualified Food Safety Auditor approved by Woolworths in order to gain certification to their standard.

Coles encourages growing teams to investigate all options available to them in their production of goods including the use of recycled materials. Coles fresh produce suppliers are required to have a formal Food Safety Program based on HACCP principles. This program must also have been audited and certified by a 3rd party, which has been accredited by JAZ-ANZ. They require this same standard to be adopted by direct and indirect suppliers. To meet the needs of a HACCP program, growers require assurances that their input products are firstly safe (meeting OH&S legislation & ensuring low microbial counts which could cause food safety issues) and secondly they are stable (they have known elements and concentrations which are not going to cause any surprises in the growing process).

The Nursery Industry has concerns primarily with legionella and other pathogens. They encourage the use of AS 4454 as a method to reduce and monitor the risks.

11. RISK MINIMISATION

Based on the findings of this project, risk minimisation strategies can be developed and incorporated into feedlot guidelines or codes. There are a number of areas however, where further information and collection of data would be useful in accurately compiling these guidelines, particularly with respect to pathogens.

Research being undertaken by the USDA into manure management will be useful in developing the Australian guidelines. However, these results are unlikely to be available until 2002 and are also concentrated on pathogens of US concern (eg *E. coli* O157:H7) which are not prevalent in Australia.

The major issue with the Australian situation is that enumerative levels of pathogens in waste are unknown. Therefore, setting time and temperature relationships in order to achieve destruction of various pathogens is difficult (ie. how many log reductions is required to achieve an acceptable level). Levels of pathogens in waste may also enable a quantitative risk assessment to be undertaken and more accurately define the risks.

Risk minimisation strategies which have been identified within the project are summarised as follows:

- Catch runoff from the feedlot in drains, and store in a holding pond. The implementation of appropriately sized vegetated buffer strips adjacent to water courses and water wells or bores will reduce the potential risk of contamination even further.

- Maintain a vegetated buffer strips onto which no manure or effluent is applied, to minimise the likelihood of groundwater and surface water course contamination when effluent is applied to pastures and crops.

- View recently arrived cattle as a source of infection for the feedlot, adding to increased loading of pathogens in waste.

- For recently arrived cattle to undergo a vaccination program and therapeutic treatment with antibiotics or other pesticides

- Ensure the quality of incoming feed.

- Set limits on the acceptable level of heavy metal contaminants present in supplies of limestone and phosphate added to feed formulations.

- Ensure the addition of trace mineral supplements is strictly in accordance to cattle requirements.

- Prevent workers inhaling contaminated dust or fluid droplets (aerosols), exercise good personal hygiene, and cover cuts and abrasions with water-proof dressings.

- Vaccinate workers against Q fever, and vaccinate cattle against leptospirosis to reduce the risk of workers contracting these diseases.

- Undertake customer end use analysis (ie development of waste-use specifications) and regularly update to ensure waste products are sufficiently treated to minimise the risk of contaminant transfer to final consumers. Feedlots must carefully consider the end market when supplying waste products, in particular only supplying materials to certain markets which have been sufficiently treated to minimise pathogen presence.

HACCP would be a highly effective tool in implementing risk management guidelines as represented in Figure 12. Using the risks identified within this project, feedlots can determine their individual risk based on best practice guidelines (which we recommend are developed from this project).

Referring to Figure 12, an example of application of the HACCP principles is follows:

Process Steps	**Hazard**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**CCP?**
Example only:							
Manure composted	Survival of *E. coli* (STEC)	Y	Y	Y			CCP
Handling of feedlot waste products	Worker contracts Q fever	Y	Y	N	Y	N	CCP

The identification and monitoring of measurement and analytical techniques will depend on the critical control points identified in the HACCP plan. As a minimum however, some monitoring of pathogen levels is required.

The inherent difficulties in testing pathogens and the associated costs were identified in Section 6.4 and therefore testing for individual pathogens is not recommended, nor warranted. Instead, monitoring of conditions that might promote pathogen growth should be considered as a primary monitoring tool. This could include:

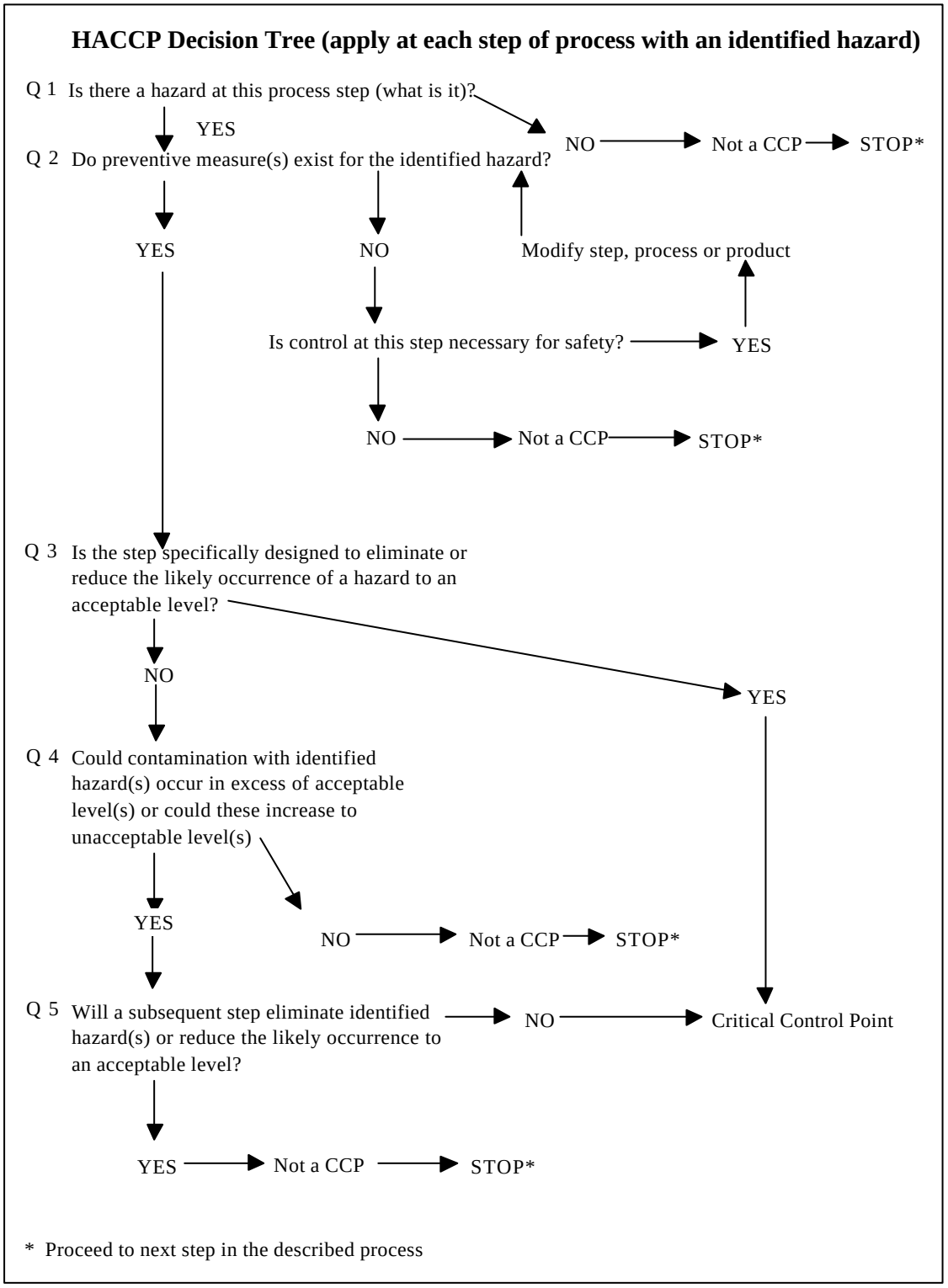
- Monitoring of time-temperature parameters; and
- Monitoring of an indicator organism (eg faecal coliforms).

Industry could also consider establishment of baseline levels of pathogens and heavy metals. Providing the levels do not increase over time, and are acceptable, then there should be no need for individual feedlots to incur the cost of on-going tests. This would also assist in providing evidence to Standards Australia to reduce the testing requirements of AS4454 for feedlot waste.

In summary the risk minimisation program for feedlots should consist of several elements:

1. Guidelines based on sound science and communication of these guidelines to the feedlot industry.
2. A HACCP plan for each feedlot based on the risk assessment in this report (eg through the NFAS program). This will more than sufficiently meet the needs of end users and could be used as an alternative to the AS4454.
3. Monitoring of conditions that might promote pathogen growth at the individual feedlot level, coupled with a wider industry program to demonstrate baseline levels of pathogens and heavy metals in waste.

FIGURE 12: HACCP DECISION TREE



12. CONCLUSIONS AND RECOMMENDATIONS

12.1 CONCLUSIONS

Contaminants most likely to be transferred from treated animal waste products to humans and animals include pathogens, heavy metals, antibiotic resistance and endocrine disruptors. The major transfer paths for contraction of the potential risk were identified as:

- Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.
- Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.
- Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals
- Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.

Without considering feedlot best practice, or actual practices, the high risks have been identified using a semi-quantitative risk assessment methodology. For humans *E. coli* (STEC) is the contaminant of concern. For cattle, the causal agents of concern are Salmonella, Mycobacterium and Clostridium. Paths of transfer include contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking; contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals; and direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.

Current waste management practices appear to be placing the feedlot industry at risk. Identified composting techniques are questionable and it is clear that industry education is required to ensure low risk practices are being followed.

In reviewing legislation, codes, standards and guidelines, there are many conflicting and confusing guidelines. The AS4454 puts an unnecessary impost on industry in terms of testing, but may not sufficiently reduce risks to an acceptable level because of pathogen regrowth. The AFFA food safety guideline for fresh produce is another guideline of relevance to feedlots supplying waste to the horticultural industry and should be used as an overall risk minimisation strategy for feedlots supplying this market.

Based on a survey of feedlots, it appears that end users of feedlot waste product are concerned about the risks associated with the product. However, provided the outcome of safe food can be achieved, and growers can demonstrate this safety (eg through HACCP and/or a risk assessment) then the utilisation of feedlot wastes should be an acceptable practice.

Measurement and analytical techniques for specific contaminants are costly and unnecessary. Instead, as part of an overall HACCP and risk minimisation program, monitoring of the safety of feedlot waste products should include a monitoring of time-temperature parameters (in composting) and testing for an indicator organism such as faecal coliforms.

Risk minimisation strategies have been identified in this study based on the researched literature.

12.2 RECOMMENDATIONS

The following recommendations have been made:

1. Research should be undertaken to quantify levels of pathogens in feedlot waste so that more accurate guidelines on waste treatment methods for feedlots can be produced (eg time-temperature guidelines for composts).

2. Feedlots should undertake a customer end use analysis and discontinue supplying inappropriate waste products to markets where an identified risk exists.

3. Using the risk management strategies and other information collected in this report, waste management guidelines should be developed

4. An industry communication strategy should be developed to ensure all feedlots are kept up to safe on best practices for the management and use of feedlot waste products.

5. Every feedlot should develop its own risk minimisation program based on HACCP that could be incorporated and administered as part of the NFAS program. The plan should include a requirement to monitor conditions that might promote pathogen growth in waste products.

6. Industry should consider establishing baseline levels of pathogens and heavy metals to reduce the requirement of feedlots to incur on-going tests. Results should also be used in providing evidence to Standards Australia for support in reducing the feedlot testing requirements of AS 4454.

7. Industry to contact Standards Australia to express concern regarding AS4454, in particular pathogen regrowth and testing requirements.

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APPENDIX 1

RISK ASSESSMENT

Campylobacter

Description of risk and transfer path	Target	Q1 Is the agent capable of causing adverse health effects	Q2 What are the consequences and severity of adverse effects	Q3 What is the likelihood of contamination	Overall score NOT considering hazard reduction at feedlot level
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	Yes. Campylobacter is a major cause of human gastro-enteritis. (1)	Major. Likely to require medical attention (0.5)	Major. All feedlots yielded Campylobacter from faecal samples (Vanselow & Hornitzky). Shown to have a prolonged survival in an aquatic environment. Have been implicated in disease outbreaks associated with the contamination of groundwater drinking supplies. (1)	0.5
	Cattle	Campylobacter do not adversely affect animal health (0)	-	-	0
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	As above (1)	As above (0.5)	As above.	
	Cattle	As above (0)	-	-	0
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals	Humans	As above (1)	As above (0.5)	Unknown and requires modelling and collection of data to ascertain whether exposure is a risk. (STOP)	Unknown
	Cattle	As above (0)	-	-	0
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	As above (1)	As above (0.5)	Medium. Campylobacter isolated in feedlot faecal samples (Vanselow & Hornitzsky 2001). Have not been implicated in any outbreaks and considered quite fragile outside an aquatic environment. (0.5)	0.25
	Cattle	As above (0)	-	-	0

E.coli (STEC)

Description of risk and transfer path	Target	Q1 Is the agent capable of causing adverse health effects	Q2 What are the consequences and severity of adverse effects	Q3 What is the likelihood of contamination	Overall score NOT considering hazard reduction at feedlot level
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	Yes. Documented cases have identified *E. coli (STEC)* as causing adverse health effects. (1)	Severe (1)	High. Isolates found in Australian waste and can survive (eg Walkerton outbreak). **NB** Most studies have been done on *E. coli* O157:H7. Australian cattle show other serotypes and unknown if similar survival rates. We are assuming similar behaviour. (1)	1
	Cattle	*E. coli* is generally not pathogenic to cattle. (0)	-	-	0
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	As above (1)	As above (1)	As above. Documented case in Japan of *E. coli* foodborne outbreak associated with irrigation water contaminated with cow manure (1)	1
	Cattle	As above (0)	-	-	0
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals	Humans	As above (1)	As above (1)	Unknown and requires modelling and collection of data to ascertain whether exposure is a risk. (STOP)	Unknown
	Cattle	As above (0)	-	-	0
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	As above (1)	As above (1)	*E. coli* identified in faeces by Vanselow & Hornitsky (2001). Eamens (2001) study on human waste showed prolonged survival of *E. coli* on pasture lands which is similar to overseas studies. Most research focused in this area and documented cases of outbreaks. (1)	1
	Cattle	As above (0)	-	-	0

Salmonella

Description of risk and transfer path	Target	Q1 Is the agent capable of causing adverse health effects	Q2 What are the consequences and severity of adverse effects	Q3 What is the likelihood of contamination	Overall score NOT considering hazard reduction at feedlot level
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	Yes. Documented cases have identified Salmonella as causing adverse health effects. (1)	Major. Unlikely to cause death in a healthy individual. (0.5)	Salmonella was present in Australian faecal samples (Vanselow & Hornitzky 2001) and evidence of survival in irrigated water. (1)	0.5
	Cattle	Yes. Cattle can suffer from salmonellosis	Severe. Death is common. (1)	As above and if cattle have access to waterways could be a potential problem. (1)	1
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	As above (1)	As above (0.5)	As above. (1)	0.5
	Cattle	As above (1)	As above (1)	As above. (1)	0.5
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals	Humans	As above (1)	As above (0.5)	Presence of Salmonella in faecal samples and evidence of air-borne transmission of Salmonella from a livestock feed processing plant causing contamination of mung beans. (1)	0.5
	Cattle	As above (0)	As above (1)	Unknown if transmission of air borne particles to animals.	Unknown
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	As above (1)	As above (0.5)	Salmonella in faeces by Vanselow & Hornitsky (2001). Eamens (2001) study on human waste showed prolonged survival of Salmonella on pasture lands. Documented cases of outbreaks. (1)	0.5
	Cattle	As above (0)	As above (1)	Documented outbreak of cattle grazing a paddock irrigated with liquid effluent. (1)	1

Coxiella burnetti

Description of risk and transfer path	Target	Q1 Is the agent capable of causing adverse health effects	Q2 What are the consequences and severity of adverse effects	Q3 What is the likelihood of contamination	Overall score NOT considering hazard reduction at feedlot level
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	Yes. *C. burnetti* causes Q-fever. (1)	Major. Chronic form of Q fever is characterised by endocarditis and acute form shows flu like symptoms (0.5)	Levels in waste are unknown as is survival of the bacterium in water. (STOP)	Unknown
	Cattle	No. Cattle do not develop any clinical illness from *C. burnetti*. (0)	-	-	0
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	As above (1)	As above (0.5)	As above. (STOP)	Unknown
	Cattle	As above (0)	-	-	0
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals	Humans	As above (1)	As above (0.5)	Levels in waste unknown. Transmission is b contact with animals faeces, urine or by inhaling dust from infected premises. Outbreaks amongst abattoir workers and people in contact with cattle are common therefore is a high risk. (1)	0.5
	Cattle	As above (0)	-	-	0
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	As above (1)	As above (0.5)	Levels in waste unknown. Transmission is b contact with animals faeces, urine or by inhaling dust from infected premises. Transmission and survival rates after contact with crops is unknown. (STOP)	Unknown
	Cattle	As above (0)	-	-	0

Leptospira spp.

Description of risk and transfer path	Target	Q1 Is the agent capable of causing adverse health effects	Q2 What are the consequences and severity of adverse effects	Q3 What is the likelihood of contamination	Overall score NOT considering hazard reduction at feedlot level
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	Yes. (1)	Major. Most cases are mild and self-limited but Weil's syndrome is a serious form. (0.5)	Levels in waste are unknown but can survive well in water. Plank & Dean (2000) reported that most humans usually can become infected through contact with urine contaminated soil and water. (0.5 or 1)	0.25 – 0.5
	Cattle	Yes but most animals carrying Leptospira may not appear to be sick. (1)	Mild (0.1)	Unknown (STOP).	Unknown
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	As above (1)	As above (0.5)	As above. (0.5)	0.25
	Cattle	As above (1)	As above (0.1)	Unknown (STOP).	Unknown
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals	Humans	As above (1)	As above (0.5)	Unknown whether transmission can be by aerosol (STOP).	Unknown
	Cattle	As above (1)	As above (0.1)	Unknown (STOP).	Unknown
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	As above (1)	As above (0.5)	Levels in waste are unknown and is reported as being able to survive well in soil. Plank & Dean (2000) reported that most humans usually can become infected through contact with urine contaminated soil and water. (0.5 or 1)	0.25 – 0.5
	Cattle	As above (1)	As above (0.1)	Unknown (STOP).	Unknown

Listeria

Description of risk and transfer path	Target	Q1 Is the agent capable of causing adverse health effects	Q2 What are the consequences and severity of adverse effects	Q3 What is the likelihood of contamination	Overall score NOT considering hazard reduction at feedlot level
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	Yes. (1)	Severe. Can result in death of foetuses. (1)	Medium. Vanselow & Hornitsky (2001) did not find Listeria in the faeces of Australian cattle. Polluted irrigated water may have been attributed to an outbreak. (0.1 – 0.5)	0.1 – 0.5
	Cattle	Yes. (1)	Severe. Can result in abortion, perinatal death, meningoencephalitis and septicaemia. (1)	As above. (0.1-0.5)	0.1 - 0.5
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	As above (1)	As above (1)	Medium. Demonstrated that can survive for months in sewage sludge applied to agricultural soils. (0.5)	0.5
	Cattle	As above (1)	As above (1)	As above. (0.5)	0.5
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals	Humans	As above (1)	As above (1)	No epidemiological studies which implicate Listeria in this type of risk. (STOP)	Unknown
	Cattle	As above (1)	As above (1)	As above. (STOP)	Unknown
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	As above (1)	As above (1)	Medium. Listeria was not found in faeces of cattle but can survive in soils for some time and implicated in previous outbreaks. (0.5)	0.5
	Cattle	As above (1)	As above (1)	Medium. Listeria was not found in faeces of cattle but can survive in soils for some time and implicated in previous outbreaks but not with cattle. (0.5)	0.5

Yersinia

Description of risk and transfer path	Target	Q1 Is the agent capable of causing adverse health effects	Q2 What are the consequences and severity of adverse effects	Q3 What is the likelihood of contamination	Overall score NOT considering hazard reduction at feedlot level
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	Yes. (1)	Major. (0.5)	Most of the serotypes isolated from bovine faeces are not normally pathogenic to humans. No outbreaks or survival studies found. (STOP)	Unknown
	Cattle	Yes. (1)	Major. (0.5)	As above. (STOP)	Unknown
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	As above (1)	As above (0.5)	As above. (STOP)	Unknown
	Cattle	As above (1)	As above (0.5)	As above. (STOP)	Unknown
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals	Humans	As above (1)	As above (0.5)	As above. (STOP)	Unknown
	Cattle	As above (1)	As above (0.5)	As above. (STOP)	Unknown
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	As above (1)	As above (0.5)	As above. (STOP)	Unknown
	Cattle	As above (1)	As above (0.5)	As above. (STOP)	Unknown

Clostridium

Description of risk and transfer path	Target	Q1 Is the agent capable of causing adverse health effects	Q2 What are the consequences and severity of adverse effects	Q3 What is the likelihood of contamination	Overall score NOT considering hazard reduction at feedlot level
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	Yes. (1)	Major. (0.5)	Low- Medium. Found to be widely distributed in the general environment overseas but actual levels in Australia are unknown. There is no strong linkage of human infections to cattle products or cattle waste products. (0.1-0.5)	0.05 – 0.25
	Cattle	Yes. (1)	Severe. Botulism in cattle is a serious disease problem and can cause significant losses. (1)	Botulism has a low sporadic occurrence in Australian cattle. Survival in aquatic environments not known. (STOP)	Unknown
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	Yes. (1)	Major. (0.5)	Low- Medium. Found to be widely distributed in the general environment overseas but actual levels in Australia are unknown. There is no strong linkage of human infections to cattle products or cattle waste products. (0.1-0.5)	0.05 – 0.25
	Cattle	Yes. (1)	Severe. (1)	Botulism has a low sporadic occurrence in Australian cattle. Survival in aquatic environments not known. (STOP)	Unknown
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals	Humans	Yes. (1)	Major. (0.5)	As above	0.05 – 0.25
	Cattle	Yes. (1)	Severe. (1)	Botulism has a low sporadic occurrence in Australian cattle. Effect of inhalation of spores on cattle unknown. (STOP)	Unknown
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	Yes. (1)	Major. (0.5)	Often found on fresh produce but no strong linkage of human infections to cattle products or cattle waste products. Given its survival in the environment, must be considered some likelihood. (0.5)	0.5
	Cattle	Yes. (1)	Severe. (1)	Outbreaks of *Cl. Botulism* documented where spreading of manure contaminated pastures which grass silage. Capacity to survive for long periods in the environment. (1)	1

Mycobacterium

Description of risk and transfer path	Target	Q1 Is the agent capable of causing adverse health effects	Q2 What are the consequences and severity of adverse effects	Q3 What is the likelihood of contamination	Overall score NOT considering hazard reduction at feedlot level
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	Link between MAP and Chrones disease not established. (STOP)	-	-	Unknown
	Cattle	Yes. Causes Johnes disease in cattle. (1)	Severe (1).	Johnes disease now endemic in most States of Australia. Animal Health Australia reports that infection can occur through the ingestion of infected faeces from contaminated pasture or water so must be considered a medium-high likelihood. (1)	1
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	As above (STOP)	-	-	Unknown
	Cattle	Yes. Causes Johnes disease in cattle. (1)	Severe (1).	As above (1)	1
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals	Humans	As above (STOP)	-		
	Cattle	Yes. Causes Johnes disease in cattle. (1)	Severe (1).	No literature which determines whether inhalation of infected particles may cause disease in cattle (STOP)	Unknown
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	As above (STOP)	-	-	Unknown
	Cattle	Yes. Causes Johnes disease in cattle. (1)	Severe (1).	Johnes disease now endemic in most States of Australia. Animal Health Australia reports that infection can occur through the ingestion of infected faeces from contaminated pasture or water so must be considered a medium-high likelihood. (1)	1

Mycotoxins

Description of risk and transfer path	Target	Q1 Is the agent capable of causing adverse health effects	Q2 What are the consequences and severity of adverse effects	Q3 What is the likelihood of contamination	Overall score NOT considering hazard reduction at feedlot level
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	Not applicable	Not applicable	Not applicable	Not applicable
	Cattle	Not applicable	Not applicable	Not applicable	Not applicable
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	Not applicable	Not applicable	Not applicable	Not applicable
	Cattle	Not applicable	Not applicable	Not applicable	Not applicable
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals	Humans	Suspected carcinogen only (STOP).	-	-	Unknown
	Cattle	Yes (1)	Major. Can cause mycotoxin poisoning. (0.5)	The actual levels in bovine waste are unknown and may not be related to levels in beef. Not known whether cattle that feed on grains containing mycotoxins will produce levels in faeces or urine that could subsequently be dispersed in the air to other animals. Levels are likely to be low in manure after absorption and degradation in gut. (STOP)	Unknown
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	Suspected carcinogen only (STOP).	-	-	Unknown
	Cattle	Yes (1)	Major. Can cause mycotoxin poisoning. (0.5)	The actual levels in bovine waste are unknown and may not be related to levels in beef. Not known whether cattle that feed on grains containing mycotoxins will produce levels in faeces or urine that could subsequently be taken up by food crops. Levels are likely to be low in manure after absorption and degradation in gut. (STOP)	Unknown

Cryptosporidium

Description of risk and transfer path	Target	Q1 Is the agent capable of causing adverse health effects	Q2 What are the consequences and severity of adverse effects	Q3 What is the likelihood of contamination	Overall score NOT considering hazard reduction at feedlot level
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	Yes (1)	Major. Disease is usually self-limiting and causes little long term damage. (0.5)	No Australian based studies on the prevalence and level of excretion of *Cryptosporidium* in cattle were found. Overseas outbreak (Milwaukee) has implicated human sewage overflow. In the Sydney water outbreak, no source found but implications for cattle waste high. Oocysts can also remain viable for long periods and are quite common overseas in rivers and lakes, especially where there has been sewage or animal contamination. (1)	0.5 assuming *Cryptosporidium* in cattle
	Cattle	Yes (1)	Minor. Causes symptomatic illnesses, mainly in young animals. (0.1)	As above. (1)	0.05
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	Yes (1)	Major (0.5)	As above. (1)	0.5
	Cattle	Yes (1)	Minor (0.1)	As above. (1)	0.05
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals	Humans	Yes (1)	Major (0.5)	Only weak evidence that oocysts can be airborne transmitted. (STOP)	Unknown
	Cattle	Yes (1)	Minor (0.1)	As above. (STOP)	Unknown
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	Yes (1)	Major (0.5)	No Australian based studies on the prevalence and level of excretion of *Cryptosporidium* in cattle were found. Overseas outbreak in apple cider implicated dropped apples contaminated with infected oocysts. The oocysts can remain viable in soil and manure for long periods. (1)	0.5
	Cattle	Yes (1)	Minor (0.1)	As above	0.05

Giardia

Description of risk and transfer path	Target	Q1 Is the agent capable of causing adverse health effects	Q2 What are the consequences and severity of adverse effects	Q3 What is the likelihood of contamination	Overall score NOT considering hazard reduction at feedlot level
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	Yes (1)	Major. Ranges from minor to chronic. (0.5)	No information on prevalence of Giardia in Australian cattle found. Most common gastro-intestinal prozoan parasite and is often implicated in water-borne illness overseas. (1)	0.5 assuming *Giardia* in cattle
	Cattle	Yes (1)	Assumed to be minor. (0.1)	As above. (1)	0.05
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	Yes (1)	Major (0.5)	As above. (1)	0.5
	Cattle	Yes (1)	Minor (0.1)	As above. (1)	0.05
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals	Humans	Yes (1)	Major (0.5)	Unknown whether oocysts can be airborne transmitted. (STOP)	STOP
	Cattle	Yes (1)	Minor (0.1)	As above. (STOP)	Unknown
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	Yes (1)	Major (0.5)	No Australian based studies on the prevalence and level of excretion of *Giardia* in cattle were found. Survival in ground faecal samples high. (1)	0.5 assuming *Giardia* in cattle
	Cattle	Yes (1)	Minor (0.1)	As above (1)	0.05

Heavy Metals

Description of risk and transfer path	Target	Q1 Is the agent capable of causing adverse health effects	Q2 What are the consequences and severity of adverse effects	Q3 What is the likelihood of contamination	Overall score NOT considering hazard reduction at feedlot level
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	Yes (1)	Major. Range of health effects both acute and chronic. (0.5)	Low. Unlikely to be in large enough levels to warrant concern. (0.1)	0.05
	Cattle	Yes (1)	Major. Range of health effects both acute and chronic. (0.5)	As above. (0.1)	0.05
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	Yes (1)	Major (0.5)	As above. (0.1)	0.05
	Cattle	Yes (1)	Major (0.5)	As above. (0.1)	0.05
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals	Humans	Yes (1)	Major (0.5)	Low. Unlikely to be transmitted via air-borne particles. (0.1)	0.05
	Cattle	Yes (1)	Major (0.5)	As above. (0.1)	0.05
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	Yes (1)	Major (0.5)	Medium. Repeated use of manure can lead to accumulation of heavy metals in the soil. However, the background level of some heavy metal compounds may be already high in the absence of animal manure. (0.5)	0.25
	Cattle	Yes (1)	Major (0.5)	As above. (0.5)	0.25

Hormones and endocrine disruptors

Description of risk and transfer path	**Target**	**Q1 Is the agent capable of causing adverse health effects**	**Q2 What are the consequences and severity of adverse effects**	**Q3 What is the likelihood of contamination**	**Overall score NOT considering hazard reduction at feedlot level**
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	Yes. (1)	Largely unknown. Possible increase in cancer risks. (STOP)	-	Unknown
	Cattle	-	-	-	-
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	Yes. (1)	As above. (STOP)	-	Unknown
	Cattle	-	-	-	-
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals	Humans	Yes. (1)	As above. (STOP)	-	Unknown
	Cattle	-	-	-	-
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	Yes. (1)	As above. (STOP)	-	Unknown
	Cattle	-		-	-

Antibiotic resistance

Description of risk and transfer path	Target	Q1 Is the agent capable of causing adverse health effects	Q2 What are the consequences and severity of adverse effects	Q3 What is the likelihood of contamination	Overall score NOT considering hazard reduction at feedlot level
Contamination of water supplies with causal agent caused by run-off into waterways used for recreation or drinking.	Humans	Yes. (1)	Severe. (1)	Overall, there is little published evidence linking bovine manure as a source of VRE that can then enter the food chain. (STOP)	Unknown
	Cattle	Yes. (1)	Severe. (1)	As above. (STOP)	Unknown
Contamination of water supplies with causal agent caused by run-off into waterways used for irrigation of food crops, pasture lands or supply of water to animals.	Humans	Yes. (1)	Severe. (1)	As above. (STOP)	Unknown
	Cattle	Yes. (1)	Severe. (1)	As above. (STOP)	Unknown
Inhalation of contaminated dust or infection of open wounds caused by application or handling of waste product. May cause air-borne particles, potentially infecting workers, neighbours or animals	Humans	Yes. (1)	Severe. (1)	As above. (STOP)	Unknown
	Cattle	Yes. (1)	Severe. (1)	As above. (STOP)	Unknown
Direct contact with contaminated soils or crops by direct irrigation with wastewater or application of solid waste.	Humans	Yes. (1)	Severe. (1)	As above. (STOP)	Unknown
	Cattle	Yes. (1)	Severe. (1)	As above. (STOP)	Unknown

APPENDIX 2

FEEDLOT SURVEY

PART 1: YOUR WASTE OPERATIONS

Reference No:

1. Please complete the following table to identify your waste products, their quantity and value and use of the products on your feedlot site.

End product produced	Yes (✓) or No (✗)	Quantity produced per year (eg in tonnes or mega litres)	Value per year ($)	% used on-site	Purpose of on-site use (eg "irrigation of peanut crops")	Method of application (eg spreading)
Solid Wastes				**%**		
Non composted solids	☐			%		
Composted solids	☐			%		
Vermicast	☐			%		
Other (please specify)	☐			%		
Other (please specify)	☐			%		
Other (please specify)	☐			%		
Liquid Wastes						
Effluent used for irrigation	☐			%		
Effluent (other use - please describe)	☐			%		
Other (please specify)	☐			%		
Other (please specify)	☐			%		

2. Please complete the following table for all end products you identified in Question 2 to provide information on treatment methods and guidelines followed (use additional paper if required).

End product produced	Briefly describe your collection and treatment method	Guidelines/regulations/standards followed (eg State/Territory legislation, codes of practice, end user supplier programs)
Solid Wastes		
Non composted solids	Utilised direct from pen ☐ Stockpiled prior to use (not turned) ☐ _____ days Windrowed prior to use ☐ _____ days Other (please specify):	
Composted solids	Average number of days composted: _____ Stockpiling method: Stockpiling watering or turning details:	
Vermicast		
Other		
Other		
Other		

Liquid Wastes		
Effluent used for irrigation		
Effluent (other use - please describe)		
Other		
Other		

3. Please describe in the following table what tests you conduct, or risk management practices you employ, to determine suitability for your waste product.

End product produced	**Tests conducted to ensure safety or integrity. Please provide a short description of the tests conducted in the following categories.** 1. nutrient balance 2. weed seed 3. pathogens (please specify) 4. heavy metals (please specify) **5.** persistent chemicals (please specify) **6.** Other (please specify)	**Other risk management practices (eg quality assurance program)**
Solid Wastes		
Non composted solids		
Composted solids		
Vermicast		
Other		
Other		
Other		

Liquid Wastes		
Effluent used for irrigation		
Effluent (other use - please describe)		
Other		
Other		

4. What skills or training are required by your management and staff to treat waste (select one or more)?

No qualification ☐
Certificate based training ☐
On the job training required ☐
Tertiary qualifications (eg engineering) ☐
Consultant employed ☐
Other (please describe) _____
_____

5. Do you compost dead cattle?

Yes ☐ → How long for? _____ days
No ☐

6. Is a site available for wet weather storage of effluent used for irrigation?

Yes ☐
No ☐

"The Market" … more questions over

PART B: THE MARKET

7. Intended market for the end product

End product produced	**Intended use (location)** 1. Used on the feedlot 2. Used on an adjacent property **3.** Used elsewhere (specify)	**Intended market** 1. Nursery industry or landscaping supplies 2. Horticultural industry 3. Rehabilitation of roads, minesites or quarries. 4. Rehabilitation of lands 5. Forestry 6. Agricultural lands 7. Energy suppliers 8. Other (specify)	**Current demand for the waste product (% of production)**	**Are you currently able to move all the waste product you want?**	**Supplier requirements (eg code of practice) for purchasing waste**
Solid Wastes					
Non composted solids					
Composted solids					
Vermicast					
Other					
Other					
Other					

Liquid Wastes					
Effluent used for irrigation					
Effluent (other use - please describe)					
Other					
Other					

8. Have any of your markets expressed concern regarding the possible health effects of feedlot waste products?

_____

_____

_____

_____

9. An issue raised during initial consultation is the cost of waste transport. For your feedlot, how significant is this issue?

_____

_____

_____

_____

10. What other barriers or limitations to marketing waste products exist?

_____

_____

_____

_____

PART C: RESEARCH AND DEVELOPMENT

11. What R&D in waste treatment or waste product development do you think is required?

_____

_____

_____

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Comments: Please feel free to note additional comments in this space.

Please return this survey to Alliance Consulting & Management in the reply paid envelope supplied by 6 October 2001, or fax to 07 3367 1150. Queries can be made to Vicki Noy on 07 3367 1113 or vnoy@allianceconsulting.com.au

We welcome feedback on this survey form