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Review of abattoir water usage reduction, recycling and reuse

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Abstract

This review examines the water quality and quantity requirements of meat processing, the wastewater quality and quantity produced, and how the wastewater can be treated to allow recycling or reuse within the abattoir. This includes an examination of the suitability of different wastewater treatment methods for the processing of different effluent streams. Also reviewed are previous MLA studies which examine what can and has been performed to reduce abattoir water requirements, and what the regulatory position is on the use of recycled water in abattoirs. Recommendations are made to direct risk assessment to be compatible with the Australian Recycled Water Guidelines. Other recommendations are made for further investigations, so as to further the goal of reducing water usage and increasing its recycling and reuse, while also meeting the public health and product quality expectations of domestic and international markets.

Executive Summary

With increasing water scarcity in Australia, the meat processing industry has an expectation to reduce its water consumption. It is preferable that this should occur through efficiency of water use and water recycling and reuse measures, as opposed to reduced production. The direction of changes in how water is used must consider consumer health and product quality, and the regulatory requirements on water usage that affect these issues.

This project aims to identify potential approaches, suitable uses, and the associated risks of wastewater recycling. This review examines the water quality and quantity requirements of meat processing, the wastewater quality and quantity produced, and how the wastewater can be treated to allow recycling or reuse within the abattoir. This includes an examination of the suitability of various wastewater treatment methods for the processing of different effluent streams. Also reviewed are previous MLA studies which examine what can and has been performed to reduce abattoir water requirements, and what the regulatory position is on the use of recycled water in abattoirs.

Abattoir process wastewaters have been characterised using reported quality and quantity information from previous MLA reports. Some wastewater streams can be expected to be suitable for reuse and recycling, while others with high contaminant loadings have a large impact on combined wastewater quality, so it may be preferable to segregate them for separate treatment. It was apparent that there is substantial variation in wastewater characteristics, and in how that information has been presented; it was concluded that improved benchmarking in this area would be beneficial.

Reported water usage between abattoirs also varied substantially, ranging from 3.8 to 17.9 kL per tonne of carcase weight produced. Some of this variation can be expected to be due to differences in water efficiency between facilities, but several other factors will also have a major influence on water usage. Further benchmarking in this area would also be beneficial, with a focus on water usage by operation or process, and note being made of other factors affecting usage. In general, water metering of abattoir processes will provide useful information for process control and estimation of water efficiency.

Process water quality requirements have historically been that water be “potable”; it has been widely perceived that export meat facilities are not permitted to use recycled water for almost any application. AQIS recognise that water recycling and reuse are becoming increasingly necessary, and have released a draft meat notice on the subject; the requirements of the notice are discussed. Some potential applications for recycled water are identified, it is noted that AQIS have approved some applications in specific instances; the validation requirements for approval of applications which have been proven at other sites can be expected to be simpler.

The technologies available for wastewater treatment to allow recycling are discussed. This includes treatment methods which are in widespread use, as well as some more advanced technologies which are suitable for the different wastewaters expected in abattoirs. No single treatment method can be expected to effectively remediate abattoir wastewaters, a combination of methods is required to perform this. It may be advantageous to critically compare some commercially-available water treatment options applicable to abattoirs, and make that comparison available to the industry.

Optimisation of the use of different treatments and of segregated wastewater recycling have potential advantages, examples of these are presented.

Implementation of any water saving innovation first requires an analysis of the costs and benefits associated with any changes, usually in financial terms. Many innovations have been documented in previous MLA publications, including cost-benefit analysis and estimation of payback period and case studies of water audits at abattoirs; these have been summarised in this report. Projected water price increases are discussed; while there is substantial uncertainty around these, it can be expected that some regions will experience large increases in water costs, making recycling more financially attractive. Cost-benefit analyses can be made more useful by accounting for water security considerations, and by inclusion of other factors such as energy and labour costs. These are becoming increasingly relevant, with some abattoirs experiencing drastic reductions in water allocations, and with emissions trading on the verge of influencing the national energy market.

Recommendations are made to direct risk assessment to be compatible with the Australian Recycled Water Guidelines. This approach uses quantitative risk assessment, examining reference contaminants to represent functional groups of pathogens or chemical contaminants. It should be readily applicable to water recycling in meat production, incorporating the comprehensive body of existing information on microbial and chemical hazards already available to the industry.

Other recommendations are made for further investigations, so as to further the goal of reducing water usage and increasing its recycling and reuse, while also meeting the public health and product quality expectations of domestic and international markets. Some of these include the use of published validations to support implementation of changed water use practices, the use of previous student studies, and with the communication of regulator decisions on water recycling with the industry.

This work will benefit the meat industry through providing advice as to the direction of future water measures for the industry. The intended outcome is that meat processors can approach reduction in water usage in a financially advantageous way while avoiding public health, quality and regulatory problems; and to help provide water security for their businesses.

Contents

1 Background

With increasing scarcity and demand for fresh water supplies in 21st Century Australia, there is an expectation that all users of the water supply find ways to reduce their demands, and become more efficient with the water they use. Large industrial water users, such as abattoirs, are particularly affected by such expectations, along with the increased financial costs of water and wastewater treatment as scarcity becomes more prevalent.

There are several ways to respond to water scarcity, many of which are already underway. Increased process efficiency with respect to water usage is becoming increasingly important, along with monitoring and benchmarking to better understand and control manufacturing processes. The use of wastewater as a resource, recycling through wastewater treatments to an acceptable quality level, is being widely examined in many industrial and municipal applications. Reuse of industrial process wastewaters to areas able to utilise lower-quality water is also becoming a more commonplace option. All of these approaches are applicable to the meat processing industry.

Meat production is subject to stringent requirements to protect public health, as well as the regulations of export markets. A requirement of water efficiency measures is that they meet the expectations of the industry regulators in a sustainable fashion. This can be seen as part of meeting the expectations of the industry's wider stakeholders, including meat product consumers in the general population.

Much water efficiency information has historically been gathered by meat industry bodies in Australia, including the MLA. A major goal of this project is to compile and review that information, and to recommend further areas of water efficiency which the industry can progress with into the future.

2 Review Objectives

This review is part of MLA's assessment of water recycling options in the meat processing industry.

The aim of this project is to identify potential approaches, suitable uses, and the associated risks of wastewater recycling. This includes:

- A review of available MLA data on quantities and qualities of effluents from various abattoir processes.
- A review of the quantities required and qualities of water that may be sufficient for various abattoir processes.
- A review of available technologies that may be used to allow the reuse of abattoir effluents for other abattoir processes.
- A review of the reuse/recycle applications already implemented in Australia in the light of possible applications.
- The recommendation of an approach to producing a risk assessment that would meet international regulatory expectations for accepting the identified possible recycle or reuse applications.
- The recommendation of further investigations required for the meat processing sector to take advantage of possible technologies to recycle or reuse effluent.

3 Abattoir process wastewater characterisation

In order to reuse or recycle a process wastewater, it is necessary to describe what can be expected to be in it, and what volumes of it can be expected to be available. While all abattoirs will be different, similar processes should generate roughly similar quantities and qualities of wastewater, allowing a general characterisation of particular processes and of combined wastewater streams.

3.1 Combined wastewater characterisation

The combined wastewater output from an abattoir has been described (MLA, 2007) as containing high levels of nitrogen and phosphorus; being of high conductivity; containing a wide variety of micro-organisms including potential pathogens; having low concentrations of cleaning and disinfection chemicals; being of neutral pH and with a temperature range from cool to hot; and containing negligible amounts of toxic compounds and heavy metals. The abattoir processes could be expected to generate wastewater with relatively consistent composition from day to day; with volume partly dependent upon the throughput of the facility, and partly dependent upon fixed water usage.

Benchmarking of the final effluent streams of abattoirs has been and is important, due to the scale of potential impact on receiving environments and sewers. The nutrient loads of the final wastewater streams from several Plants are compared in MLA (2005). Substantial variations between sites were observed; with nitrogen loadings ranging from 0.25 to 0.57 kg per tHSCW (tonnes hot standard carcase weight), and phosphorus loadings ranging between 1.3 to 3.6 kg per tHSCW. This was interpreted as a difference in efficiency between the plants, indicating that some were performing well and others with room for improvement. Also referenced in the appendices of this report is a UNEP (United Nations Environment Program) fact sheet for cleaner production in the food industry, which discusses organic loading of red meat abattoir wastewater. This cites COD (Chemical Oxygen Demand) values of wastewater as being approximately 48.5 kg COD per tHSCW for operations with rendering, and approximately 13 kg COD per tHSCW for operations without rendering. The approach of expressing contaminant loadings in relation to abattoir production is most appropriate when examining total outputs of the plant; however when examining wastewater for reuse or recycling suitability it is of more use to describe volumes of flow and concentrations of contaminants.

3.2 Process-specific wastewater characterisation

The major areas of abattoir wastewater generation have been described as follows (MLA, 2007):

Figure 1: Wastewater generation areas

Facility area	Flow volume	Strength
Stockyard	Medium	High
Slaughter/Evisceration	High	Low
Offal processing	Medium	High
Rendering	Low	Very high

In this context, “Strength” refers to the concentration of the wastewater constituents. In general, it could be suggested that wastewaters of high flow and with low concentrations of contaminants would be most suitable for subsequent reuse or recycling; and wastewaters of low flow and high strength may be suitable for segregation and alternative treatment methods, so as to reduce contaminant loading in the combined wastewater.

An example breakdown of the loading of different contaminants to waste water is cited in MLA (2002) (originally from MLA 1995b), and is reproduced below. The contaminant loadings described in relation to production efficiency rather than concentration and suitability for recycling or reuse.

Figure 2: Example breakdown of abattoir wastewater pollutant loads (kg per tHSCW)

Source	COD	N	P	Na	TSS	O&G
Stockyards	1.20	0.18	0.04	0.03	0.50	-
Slaughter & evisceration	3.75	0.54	0.04	0.75	0.95	0.35
Offal processing	3.95	0.30	0.05	0.16	0.75	0.55
Boning rooms and chillers	0.30	0.10	0.00	0.01	0.40	0.05
Paunch dumping	8.20	0.40	0.19	0.87	1.55	2.45
Gut washing	0.50	0.18	0.03	0.40	0.50	0.04
Raw material bin drainage	6.00	0.43	0.05	0.10	0.95	7.50
Blood processing	3.13	0.22	0.08	0.13	0.54	0.10
Tallow processing	18.00	0.11	0.03	0.08	7.5	10.00
Cooker condensate	0.94	0.11	0.01	0.05	0.05	0.03
Total	46.0	2.5	0.5	2.6	13.7	21.1

The processes contributing the highest loading for each contaminant are shaded in the table above.

Wastewater streams can also be described by their expected constituents. Examples include the “green” waste stream, generated from manure, paunch wastes, and stockyard washing, emptying of the animal stomachs and further processing of the internal organs; and the “red” waste stream, containing water contaminated with blood and fats, which has been generated from carcase washing and related abattoir hygienic practices (MLA, 2007).

Several previous MLA studies have characterised wastewaters from different abattoir processes, some in substantial detail. Some of these project reports are summarised below as case studies and in order to characterise the quality and quantity of different effluent streams.

3.3 “Potential for reuse of low contamination abattoir effluent streams”

The MLA PIP.010 report “Potential for reuse of low contamination abattoir effluent streams” involved the characterisation of several wastewater streams in a bovine abattoir. In this study, large volumes of reasonably high quality wastewater were found to be available from viscera table boot wash wastes (34 kL/day), the viscera table cold washes (31 kL/day), and the combined steriliser wastes from the combined hide on area (20 kL/day). The quality of the wastewaters was determined by a combination of physical, chemical and microbiological criteria; the exact parameters used and values observed were not discussed.

These waters were collected along with other medium or high quality wastes (10 kL/day of hand wash wastes and 8 kL/day of viscera table hot water wash wastes), and combined into a reuse stream. This stream was screened to remove large solids, chlorinated, and was characterised as follows:

Figure 3: Example reuse stream characteristics

Projected daily volume: 104 kL
Temperature (average): 53°C
COD: 70 mg/L
Total phosphorus: 0.4 mg/L
Total nitrogen: 5 mg/L
Oil and grease: 5 to 10 mg/L
Suspended Solids: 10 mg/L
Total Plate Count: 700 CFU/mL
Total Coliforms: 60 CFU/mL

This includes the major chemical and microbiological contaminant parameters. Other chemical and nutrient parameters were also examined, including those of relevance to tanning processes, which was the intended purpose of reuse for the water.

3.4 “A nitrogen management strategy for meat processing plants”

The MLA report PRENV.012 “A nitrogen management strategy for meat processing plants” also characterised wastewater streams. Nineteen individual wastewater streams were sampled and tested, and grouped into three categories according to composition.

“Very high strength” streams were characterised by COD of >50,000 mg/L, TSS of >20,000 mg/L, O&G of >7,000 mg/L, TN of >3,000 mg/L, and TP of >200 mg/L; with much variability in these values. These streams included raw material bin (RM bin) drainage, and tallow stickwaters from polishers and a low-temperature rendering plant.

“Medium strength” streams were characterised by COD of 14-20,000 mg/L, TSS of >7,000 mg/L, TN of >340 mg/L, and TP of >150 mg/L. These streams included cattle yard wash water, tripe processing effluent, and a dry dump stream; some of these streams were typically high flow.

“Low strength” streams were typically characterised by COD of <6,000 mg/L, TSS of <2,000 mg/L, TN of <250 mg/L, and TP of <25 mg/L, although with much variability. This included the red offal wash stream, which contributed almost half the total discharge load of oil and grease.

World Best Practice benchmarks for contaminants in facility wastewaters were also cited in this report originally sourced from work performed by Dr Mike Johns for MLA and Australian Country Choice. These benchmarks were noted for wastewater generation (5.5 kL/tHSCW), COD loading (30 kg/tHSCW), TN loading (1.5 kg/tHSCW), and TP loading (0.25 kg/tHSCW).

This study also ranked the facility waste streams according to their contribution to total load discharged, for each of the main contaminant parameters. A table of this data is reproduced below. This data was of plant performance prior to modification to reduce loadings in wastewater.

Figure 4: Example primary sources of wastewater contaminant loading

Ranking	TCOD	TSS	O&G	TN	TP
1 (worst)	RM Bin (22%)	Cattle yard wash (38%)	Red offal wash (48%)	RM Bin (32%)	Cattle yard wash (32%)
2	Cattle yard wash (20%)	Tripe process (15%)	Tripe process (26%)	Cattle yard wash (17%)	RM Bin (17%)
3	Tripe process (17%)	RM Bin (14%)	RM Bin (8.6%)	Tripe process (9%)	Dry dump (15%)
4	Red offal wash (10%)	Red offal wash (11%)	HT Stickwater (5%)	DCB process (7%)	Red offal wash (11%)
% of total emission	69%	78%	87.6%	65%	75%

The four processes contributing the most contaminant loading were identified as the ante-mortem yard (cattle wash yard), the raw material bin drainage, the red offal wash, and the tripe processing. In comparison, the streams contributing the greatest wastewater flows were (in order of volume) the kill floor red flows, the ante-mortem yard flow, the tripe processing flow, the cleaning flows from the kill floor and boning room, and the boning room flow. This illustrates that the streams contributing the most contaminant loading are not necessarily those with the largest flow volumes.

3.5 A facility review of pollutant loads in abattoir wastewater streams

Another useful case study is the facility review of pollutant loads in wastewater streams performed on the abattoir at Wagga Wagga (Johns, 2001). Six primary waste streams were characterised in this report, combining into red and green streams. The facility includes a high temperature rendering plant, which processes material generated on–site. The facility generates approximately 2.8 ML/day of effluent, made up of quantities modelled from separate processes as described below (table from Johns, 2001):

Figure 5: Example wastewater stream flows by process

Stream	Modelled flow (kL/day)	% of flow
Kill floor white	780	27.7
Kill floor red	200	7.1
Red offal wash	150	5.3
Boning rooms	160	5.7
Kill/Boning cleaning	160	5.7
Byproducts	*(295)*	*(10.5)*
- Raw material drainage	90	3.2
- HTR condensate	70	2.5

- HTR tallow stickwater	25	0.9
- Blood stickwater	30	1.1
- Ring drier scrubber	50	1.8
- Miscellaneous	30	1.1
Wet paunch dump	200	7.1
Offal wash (green)	150	5.3
Antemortem yards	580	20.6
Truck wash	50	1.8
Human sewage	90	3.2
Total flow	**2,815**	**100**
Red stream	1,745	62.0
Green stream	980	34.8

Note: "Kill floor white" comprises steriliser, hand wash, and other "clean" flows
Kill floor red comprises "dirtier" flows
Byproducts incorporates the six flows below it
HTR = High Temperature Rendering
Offal wash (green) = tripe washing/refining flows

The composition of the wastewater streams at this facility were estimated as follows (data in mg/L; table from Johns, 2001):

Figure 6: Example wastewater contaminant concentrations by process

Stream	**COD**	**SS**	**O&G**	**TN**	**TP**	**AN**	**BOD**
Byproducts							
Raw Mat Bin drain	68,000	22,000	1,700	6,200	510	40	32,000
HTR condensate	900	25	50	325	5	200	550
Blood stickwater	35,000	13,500	20	4,000	55	15	21,000
Offal processing							
Paunch dump wet	16,500	25,000	3,500	430	120	110	6,000
Offal wash (green)	23,000	11,000	2,500	850	68	40	12,000
Antemortem yards	2,000	800	150	310	31	190	380
Saveall	7,890	3,750	654	353	40		
Green stream	7,300	6,000	1,000	225	47		
Red stream	6,500	2,300	456	400	38		

AN = Ammonia – Nitrogen concentration
COD = Chemical Oxygen Demand concentration
SS = Total Suspended Solids concentration
O&G = Oil and Grease concentration
TN = Total Nitrogen concentration
TP = Total Phosphorus concentration
BOD = Biological Oxygen demand, based on 5-day test.

The flow volume and contaminant concentration data was used to calculate loadings of the different contaminants, and which of the wastewater streams had most effect on combined wastewater quality. A small number of streams contributed most of the contaminant loading; these were identified as the Raw Material Bin drainage (particularly for COD, TN, TP), paunch dumping and hasher washer (O&G and TSS), antemortem yards (nutrients), and tripe processing and green offal washing. These streams were identified for either elimination or segregation and treatment.

3.6 Assumed wastewater characteristics for membrane processing

A study examining the potential for processing abattoir wastewater streams using membrane technologies (MLA, 2005b) examines the strengths and weaknesses of those technologies for treating various waste streams. It concludes that such treatments are technically possible, and should be continued to be assessed by the industry. Assumptions are made in this study as to the quantity and quality of some wastewaters, in order to match those characteristics with treatment technologies. The assumed characteristics are as follows:

Stickwater
Flows usually of 5-30 kL per day, depending on throughput. Usually dumped to the wastewater treatment system, or evaporated in waste heat evaporators. Wastewater characteristics are as follows:

Figure 7: Example stickwater characteristics

Temperature: 80-90°C
COD: 100,000 mg/L
TSS (from fine solids): 20,000 mg/L
Nitrogen: 2,000 to 4,000 mg/L
Phosphorus: 200 to 300 mg/L
Oil and grease: 1% to 2% w/v

Steriliser and hand wash water
Steriliser water is high temperature (82°C) and generally high quality, with traces of organics and nutrients, and low levels of microorganisms. Hand wash and table wash water is cooler (43°C) and may be slightly more contaminated. Flows of 50 to 200 kL/day were assumed for steriliser water, and triple that for combined flows.

Plant effluent
The combined Plant effluent was estimated as having flows of 1 to 6 ML/day. Treatment in activated sludge systems including sequencing batch reactors was projected, and the effluent was assumed to have the following quality characteristics:

Figure 8: Example combined plant effluent characteristics

COD: 120 mg/L
Total Nitrogen: 20 mg/L
Total Phosphorus: 1 mg/L
Total coliforms: 200,000 per 100mL

4 Abattoir process water requirements

This section reviews the quantities and qualities of water required for the various abattoir processes. Historically, water has often been regarded as a plentiful resource, with efficiency of its use not being a priority. This has led to a wide variation in the amounts of water being used when comparing different abattoirs, presumably due to differences in manufacturing practices. The previous abundance has also resulted in the quality of process water usually been required as “potable” as a default, including for processes where use of lower quality water would carry little or no risk. Water scarcity and cost is now leading to re-examination of these requirements.

4.1 Total water consumption

Water usage and consequent wastewater generation in abattoirs can be expected to be 10-11 kL per tonne of carcase weight produced in large integrated export facilities, and 3-5 kL per tonne in small domestic facilities. Industry measurements of water usage in 2003 ranged from 4-18 kL/tHSCW, depending on size, product market and export requirements (MLA, 2007).

The environmental performance of a representative set of medium-large abattoirs, examined between 1998 and 2003, is reported in MLA (2005). This study used selected key performance indicators (KPIs) to measure comparative performance. The industry trends identified were generally that resource use and waste production remained relatively steady over the study period. Water usage decreased somewhat over the study period (with a decrease of about 11%, from 11.8 to 10.6 kL per tHSCW produced), although the statistical significance of this is uncertain. Water usage reductions were attributed to water-saving innovations such as motion sensors and employee education; with wide variations between plants (ranging from 3.8 to 17.9 kL per tHSCW). This was interpreted as indicating that some plants were performing very well, while there was room for improvement at others. Much of the data between 1998 and 2003 cannot be directly compared due to changes in which plants were examined, changes in throughput and product lines, and changes in environmental conditions. However, of the four plants examined in both studies, average water usage per tonne of product had reduced by 7% in the intervening five years.

It can be expected that much of the variation in water use between abattoirs results from differences in exactly what the facilities are doing, in the scale of their operations, in what their state or AQIS regulations require of them (or are perceived to require), and from local particular circumstances such as the price and availability of water. These factors complicate the process of benchmarking water use between facilities; care should be taken when examining the relative water efficiency of any given abattoir.

4.2 Process-specific water consumption

Given the wide range of differences which can be expected when benchmarking water usage in abattoirs, it is likely to be more effective to examine the specific processes where the water is used. Generating the data to do this requires water metering for those specific processes; this has become increasingly widespread in the industry as water efficiency has become a more pressing issue. Expected process water usage has been detailed in some previous MLA reports, for the purpose of providing a benchmark for the industry.

MLA (2002) provides an overview of water use at a “typical” plant. This identifies the major water use processes at such an abattoir, noting that water usage varies substantially between facilities. Usage is divided into fixed requirements for maintaining basic plant operations, and variable requirements dependent upon plant throughput.

Figure 9: Example water consumption by process area

Area of Usage	**Percentage of fresh water consumption**
Variable Water Use	*(55%)*
Stockyards	25%
Slaughter and evisceration	10%
Paunch, gut and offal washing	20%
Fixed Water Use	*(45%)*
Rendering	2%
Sterilisers and wash stations	10%
Amenities	7%
Plant cleaning	22%
Plant services (cooling, heating)	4%
Total	**100%**

Similarly, a breakdown of water usage by process area has been described in MLA (2007); with the water usage data presented as a range so as to reflect the wide differences between facilities.

Figure 10: Second example water consumption by process

Area of Usage	**Percentage of fresh water consumption**
Stockyards (mostly washdown)	7 - 24%
Slaughter, evisceration	44 – 60%
Boning	5 – 10%
Offal processing	7 – 38%
Casings processing	9 – 20%
Renderings	2 – 8%
Chillers	2%
Boiler losses	1 – 4%
Amenities	2 – 5%

Several previous MLA studies have characterised water use from different abattoir processes, some in substantial detail. One of these project reports is summarised below as a case study, and in order to characterise water quantity requirements; other reports have been summarised later in this document (Section 6.4 – Case studies of water usage reduction measures in Australia).

4.3 Water metering and usage at a large sheep meat abattoir

A case study examining water metering and usage at a large sheep meat abattoir in Dubbo (MLA report PIP.134; MLA, 2006) usefully demonstrates water usage by the different abattoir processes. Following the establishment of a water flow diagram and installation of meters, the overall water use balance for the facility was estimated as follows:

Figure 11: Sheep abattoir water consumption by process

Section	Usage / week (kL)	% of total
Slaughter floor	6,115	36.44
Fellmongery	95	0.57
Pet food	45	0.27
Salt shed / pickle shed	26	0.15
Boning rooms	448	2.67
Wool scour	3,614	21.54
Wool tops	1,981	11.8
By-products	1,029	6.13
Stockyards	32	0.19
Steam usage	1,604	9.56
Condenser use	482	2.87
Total	15,472	92.19
Missing	1,311	7.81

The slaughter floor water usage was the highest in the facility. This was further broken down, as follows:

Figure 12: Sheep abattoir slaughter floor water consumption

Application	Usage / week (kL)	% of total
Sterilisers	1,369	8.16
Night cleaning	1,250	7.45
Ante room	300	1.79
Other process uses	3,196	19.04
Total	6,115	36.44

4.4 Water quality regulatory requirements

With regard to water quality for water used in abattoir processes, the major regulatory requirement to be met is the (draft) AQIS meat notice (AQIS, 2008). This document covers water recycling, either on- or off-site, which has been treated to potable or fit-for-purpose levels. It has been written in response to a perceived general need to reduce water consumption, while addressing food safety concerns through use of HAACP and modern water recycling technologies. Water quality requirements for process use have historically been that the water be “potable”.

Terminology is defined in AQIS (2008) for several water types (recycled, indirect planned potable, direct planned potable, potable and reused waters). Of note is that “direct planned potable recycled” water is used solely within that establishment, and meets the ADWG criteria for potable water; and that “potable” water is water from any source that is acceptable for human consumption. Establishments wishing to use direct planned reuse must provide full details to AQIS prior to construction, and also for final approval once validated prior to use in production. Other regulators (local councils, health and food authorities) must also be informed and consulted. With “indirect potable reuse”-sourced waters, the risk is with the supplying water authority. Indirect reuse involves advanced treatment of municipal sewage to purify it to a high quality, the product water is then used as an input for drinking water catchments. The responsibilities of the occupier and of AQIS are also defined in this document.

Export registered establishments wanting to use reuse water need to apply through AQIS (see AQIS, 2008). The legal position for recycled water is that it is suitable for abattoir processes, as long as it is potable and considered an input under HAACP (the relevant standard is AS4696:2007). The future legal position will be defined via a national guidance document. The requirements for recycled and reused water have been taken into account in the approach AQIS have taken in this document.

Direct planned potable recycling has the following requirements noted in AQIS, 2008:

- Must stay on the establishment, no on-selling of product water
- Exclusion of human effluent from wastewater streams
- No physical connection between potable and non-potable supplies
- Use HAACP
- Multiple barrier approach to ensure treatment redundancy in case of failure
- Ensure access to local potable supply or alternative in case of system failure
- Water meets ADWG standards for drinking water
- Recycled water is not a direct ingredient in meat products

Reuse of wastewater in other areas has the following requirements (noted in AQIS, 2008):

- Excludes human effluent
- No physical connection between the potable and recycled supplies
- Follows HAACP principles (may include treatment of further steps to remove risks)
- Alternative potable supply is available

Several examples are given for reuse processes which have already been given approval by AQIS, a list that is expected to grow. It is noted that facilities will still require individual approval following a defined analysis and management process.

- Steriliser and hand-wash water collected and used to wash cattle yards
- Carcase decontamination water, roughly filtered and maintained at pathogen-lethal temperature, reused for same process
- Water from clean end of viscera table reused for initial viscera table wash
- Steriliser water reused to wash moving dry landing area
- Tertiary treated wastewater used to wash yards and initial wash of stock
- Chlorinated tertiary treated water used to wash yards and final wash of stock

Although not defined in the notice, it is assumed that the tertiary treated wastewaters referred to are sourced from the combined plant effluent, excluding human sewage from the facility toilets.

The AQIS documentation (AQIS, 2008) also includes “A guide for meat businesses wishing to reuse water”. This includes the following process, described in discrete stages:

Stage 1: Self assessment prior to preliminary meeting with regulators

- Stakeholder analysis
- Water audit
- Assessment/characterisation of source water
- Treatment systems
- Internal business management assessment by Company
- Preliminary meetings with other relevant stakeholders

Stage 2: Risk management through to submission for approval

- Commission Risk Assessment
- Identification of Control Points/Critical Control Points/Control Limits
- Submission to AQIS for approval

Stage 3: In-principle agreement

Stage 4: Validation to Commissioning

- Validation
- Monitoring (Validation/Verification and Operational)
- Reporting
- Other considerations during validation
- Revalidation of processes
- Steps in the validation process
- Assessment of Validation by AQIS

Stage 5: Approval and ongoing monitoring/verification/reporting

- Approval by AQIS
- Ongoing monitoring of system, with records subject to audit by AQIS
- Verification undertaken by controlling Authority
- Possible statutory reporting requirements

5 Treatment allowing water reuse within the abattoir

Much of the technology available for treatment of abattoir process wastewater is already familiar to the industry, being used extensively for the treatment of wastewater prior to discharge to the sewer or the receiving environment. This section describes those widely utilised treatment processes, as well as some of the more advanced technologies which may be less familiar to the industry.

5.1 Aims of wastewater treatment

The incorporation of appropriate treatment processes can result in recycled water of a standard which is fit for various identified uses at an abattoir.

Historically, treatment has been performed to allow discharge of wastewater to sewers or the receiving environment. This has often involved trade waste charges, so treatment has aimed to reduce these charges by reducing volume of wastewater and concentration of contaminants.

Wastewater treatment can also be applied so as to recover of lost product from wastewater streams (MLA, 2002), potentially resulting in financial benefit from increased production and from reduced trade waste discharge costs.

5.2 Widely-utilised wastewater treatment processes

Best practice wastewater treatment has previously been extensively described, along with the main goals of the different treatment levels (MLA, 2007). Disposal paths have historically been noted as via sewer, via irrigation, and via surface waters; with different quality requirements for wastewater streams dependent upon disposal path. These treated effluents of various qualities are potential source waters for recycling processes.

Wastewater treatment is discussed in MLA (2002); with the different types of physical contamination defined for the different contaminant sources, the effectiveness of the different treatments in removal of the different contaminant, description of other treatment inputs such as electricity and chemicals, and example costs for wastewater treatment and disposal. Available technologies for treatment of wastewater are extensively described in MLA (2007), along with tips for treatment process operation and an appendix on waste minimisation strategies. The different qualities of product water may be usable for different reuse applications. The treatments noted are briefly described below.

5.2.1 Primary treatments

Primary treatment aims to remove coarse and suspended solids, oil and grease.

- **Static and vibrating screens.** Screening separates solid materials from wastewater, using gravity, water action, and mechanical forces. Screens are robust and low maintenance. Vibrating screens less easily blocked by solids, but are susceptible to mechanical failure. The screens require periodic cleaning, and are not suitable for fat-laden material.

- **Rotary screens.** These are rotating cylindrical wire screens. They are easily cleaned, can handle flow surges, and are more efficient with fatty effluent than other screens. There is a risk of mechanical failure with high fat or fibrous solid loadings, a requirement for regular cleaning, and solids removal is limited by the screen characteristics.
- **Screw press.** Uses a press combined with a screen with a screw augur to produce a dry solid discharge. Screw presses are effective for screening and dewatering solids. They have a high wear rate, and may release more contaminants to wastewater.
- **Hydrocyclones.** Use centrifugal force to separate solids or fats in a conical separator with no moving parts. These units are small and less affected by high water temperature than other methods. They require the use of a pump, and are susceptible to blockage from fine solids and fat.
- **Save-all.** A tank allowing floatable materials to rise and settled solids to sink. These are cost-effective for fat removal, extracted as a useful by-product; and allow easy solids removal. They operate at low efficiency under high flow and high temperature conditions, are large, and can result in odour problems.
- **Electrocoagulation.** Uses ionic flocculant dosing with an electrical field to remove solids. Highly effective on low volume, high strength streams; and removes phosphorus. However, is unproven in dilute, high-volume streams, and generates large volumes of unstable solids.
- **Dissolved Air Flotation (DAF).** Uses pressurised air to float fats and solids for removal, can be assisted with chemical flocculants. Very efficient at fat removal, chemical DAF also effectively removes solids, BOD, and nutrients. Process is reliable and relatively small, but removes fats poorly at high water temperatures, and chemical dosing generates high sludge volumes.
- **Induced Air Flotation (IAF)** or **Cavitation Air Flotation (CAF).** IAF uses a pump or venturi to produce bubbles, which are larger but fewer than a DAF system. IAF is simpler than DAF, requiring no pump and less energy; and is more efficient than a Save-all. However it is less reliable, and it is difficult to control air saturation.

5.2.2 Biological treatments

These secondary treatments aim to remove nutrients, organics, and pathogens.

- **Aerated pond.** Achieves microbial breakdown of organic material under aerobic conditions, with air usually provided using surface aerators. Is reliable, simple, and low-odour; with good BOD removal. However requires a large space, power supply, and effluent contained high solids concentrations.
- **Anaerobic pond,** with natural or synthetic cover. Achieves microbial breakdown of organic material under anaerobic conditions. Is simple, robust, and cost effective. Can produce odour problems, and effluent requires further treatment.

- **Facultative pond.** Combines aerobic and anaerobic breakdown. Is reliable, simple and low-maintenance. However, needs a large area, and can have algal bloom problems and seasonally-affected performance.

- **Maturation pond.** A shallow and highly aerobic pond, similar advantages and disadvantages to facultative ponds.

- **Activated sludge.** Recycles sludge so as to maintain high bacterial levels in an intensified aerobic pond. It is a rapid and versatile process capable of generating high quality effluent. However, it is expensive to build and operate, and vulnerable to upset.

- Nutrient removal through use of **activated sludge**. Capable of cost-effective nitrogen removal.

- **Wetlands.** An alternative to maturation ponds, using plants in a shallow soil matrix. Are suitable for specific sites, with planning, and achieve good removal of solids and pathogens. Require a large area and low feed concentrations, and produce unpredictable effluent quality.

5.2.3 Tertiary treatments

These aim to further remove pathogens by disinfection.

- **Chlorination.** Addition of chlorine gas or sodium hypochlorite to kill microorganisms, particularly bacteria. Is simple and cost-effective, but produces some toxic by-products, and is temperature and pH dependent.

- **UV irradiation** of wastewater. It is an effective, rapid, and chemical-free process, and does not require much space. Requires regular cleaning and replacement, vulnerable to fouling and high turbidity.

5.2.4 Other treatments

Wastewater treatment can have the aim of product recovery, with the advantage that removal of such material reduces contaminant loading of the resultant stream. Some treatments with this objective are described in MLA (2002), as follows:

- **Static wire screening.** Lost solids can be screened directly downstream of a process and then transferred to rendering, ensuring the quality of the recovered product remains high.

- **Segregation of hot water streams to improve fat recovery.** Hot wastewater streams with low level of contaminants (such as water from knife sterilisers) can bypass fat-recovery treatments such as Save-alls. Temperature reduction in Save-alls can substantially improve fat recoveries.

- **Stickwater solids recovery using evaporation.** Stickwaters can be processed using a Double Effect Evaporator (DEE), involving heating the liquid with steam while the liquid is under vacuum. This can be an alternative to treatment and disposal of stickwater.

- **Stickwater solids recovery using ultrafiltration.** This involves processing through selective membranes, which concentrate the total solids and allow subsequent drying back in the rendering plant.

5.3 Advanced treatment processes

Developments in treatment technology have resulted in the potential for application with abattoir wastewaters. Some examples of these developments are described below.

5.3.1 Hydrocyclones

The removal of fats, oil and grease is a particular requirement for the treatment of wastewaters from many abattoir processes. To date, the most effective and widely used treatment to accomplish this has been dissolved air flotation (DAF). However, hydrocyclones appear to be able to achieve similar results, in a more cost-effective fashion, and with a smaller equipment footprint.

A study examining actual performance of hydrocyclones on meat-processing wastewater (MLA, 2003c) found they removed oil and grease from process wastewaters to a similar standard as other available technologies. In particular, the capital and operating cost of solids and O&G removal was found to be significantly less than normal DAF treatment; and the short residence time and resultant improved fat quality had significant advantages when compared to other treatments such as the Save-all.

5.3.2 Membrane treatments

There are a variety of membrane treatment options available which may have potential application for abattoir wastewaters. The choice of membrane treatment system is dependent upon the quantity and quality of the wastewater which is to be treated, and the required results from that treatment. This is further discussed in detail in MLA (2005b), where three scenarios were considered – the treatment of stickwater, the remediation of steriliser-hand wash wastewater, and effluent reclamation.

For stickwater treatment, potentially suitable membrane treatments were identified as the Vibratory Shear Enhanced Process (VSEP), a rotary membrane device involving a stationary housing and a rotating disc membrane, and a ceramic membrane. Capital costs for systems capable of processing 30kL per day ranged from $215K to $285K, with processing costs per kL ranging from $3.20 to $3.90.

The remediation of steriliser-hand wash wastewater was considered with polymeric cartridges, ceramic membranes, and microsieves. Capital costs for systems capable of processing 50kL per day ranged from $34K to $48K (with cartridges not requiring capital expenditure), with processing costs per kL ranging from $0.13 to $0.50.

The reclamation of combined plant effluent was assessed for an effluent stream of 1-6 ML per day; with membrane treatment systems considered including dual membrane reclamation of secondary effluent (micro- or ultra-filtration followed by reverse osmosis), one-step reclamation of effluent (micro- or ultra-filtration only), and the use of membrane bioreactors with subsequent reverse osmosis. The cost estimations for these systems were highly variable, depending upon the source wastewater quality, the scale of operation and the exact equipment used; processing costs per kL ranged from $0.20 to $2.00.

Overall, it is noted that it is technically possible to treat wastewater using membrane technologies to a potable standard. However, the feasibility of any such scheme is dependent on a cost-benefit analysis, incorporating the particular circumstances of any individual site.

5.3.3 Moving bed bioreactors

Moving Bed Bioreactor (MBBR) technology uses specially designed plastic carriers to grow the biomass on. The carriers are inside the reaction tank and are suspended in the water by the movement of the sparged air. MBBR technology allows a high rate of BOD breakdown due to the very high surface area of the carriers and as the process is aerobic a source of oxygen is required, usually blowers that provide air to the system. MBBR systems are easier to control than activated sludge systems and can deal with the very high strength waste water that is typical of abattoirs. The advantages of MBBR systems include:

- a smaller size bioreactor than standard activated sludge system;
- possible to use coarse bubble aeration that eliminates the need for expensive diffusers;
- sludge bulking is not a problem because the solids are separated independently of the biomass settling properties;
- system able to deal with a certain level of free fats;
- foaming not normally a problem;
- improved effluent quality due to more efficient solids removal and the ability to tertiary treat the water in process, such as through phosphorus removal by the addition of iron salts.

5.4 Technology comparison and suitability for reuse applications

This section outlines the suitability of various technologies in treatment of individual contaminants in wastewater and their potential use within various waste streams that emanate from a typical abattoir facility.

5.4.1 Principal Contaminants

The principal contaminants in wastewater that need to be considered from a water reuse viewpoint are:

- Biological oxygen demand (BOD) as well as chemical oxygen demand (COD). Factory effluent can be assessed for its suitability to biological treatment by examining the BOD/COD ratio. The ratio is obtained from chemical analysis and if the ratio is 0.5 or greater then the wastewater is easily treatable by biological means. Total BOD is also used by sewer operators as a parameter to charge for wastewater discharge.

- Total suspended solids (TSS) is a measure of the amount of insoluble material suspended in the wastewater. Depending on the size of the solids, screening or filtration can remove a considerable amount of TSS.
- Total dissolved solids (TDS) is a measure of the amount of dissolved material in the wastewater and can consist of dissolved organic material (can be soluble BOD or refractory BOD) as well as inorganic salts. Chemical treatment and pH adjustment of wastewaters add to the TDS.
- Oil and grease (O&G) are the fats, both free fats and emulsified fats that are present in the wastewater. Fats in abattoir effluent arise from the carcasses and the quantity of fat in the effluent depends upon the level of fat recovery in the factory and such effluent characteristics as temperature, cleaning chemicals, pH and dissolved organics. Fats in an effluent stream cause filter blockage, high oxygen demand, reduced oxygen transfer efficiency and contribute significantly to odour. In any wastewater treatment system it is good to remove the fats as early as possible in the process.
- Phosphorus (P) in the wastewater results from the blood products in the water and any phosphate chemicals used in the plant. Biological systems, whether anaerobic or aerobic require some phosphorus to ensure biomass growth, but excess phosphorus can be a real problem for effluents going to spray irrigation, as the P accumulates in the soil, and water discharged to rivers/creeks as the P promotes algae growth.
- Nitrogen (N) can be in a number of forms in wastewater. Abattoir waste can have urea, ammonia, nitrates and nitrites as well as N associated with proteins. Nitrogen levels in wastewater are usually treated by the combination of aerobic and anoxic conditions, such that the N escapes from the treatment system into the atmosphere as nitrogen gas. The nitrification/de-nitrification process will be examined in detail later in this Section.

Other effluent characteristics that are important in reuse and discharge are temperature, pH and pathogen levels.

5.4.2 Process Suitability for Specific Contaminants

Section 5.2 outlined the main wastewater treatment processes that are used and/or available for the treatment of abattoir effluent. The processes are grouped under the sewage treatment vernacular of Primary, Secondary and Tertiary treatment. However, for the treatment of wastewater from industrial applications it is better to group the processes under the process descriptions of physical/chemical, biological and membrane. The reason for classifying the processes in this manner is that wastewater quality improves with each successive process step from physical/chemical to biological to membrane, and there is a corresponding cost differential. As to what combination of unit processes are included in any treatment system, will depend upon the contaminant type, final quality required and potential future reuse.

Figure 13 below shows the suitability of each process class to treating the main contaminants found in most industrial effluents

Figure 13: Treatment system effectiveness for contaminant removal

Treatment	BOD	SS	TDS	O&G	P	N
Physical /Chemical Systems	Partial 40% to 80%	Good	Virtually nil removal	Good	Good with Chemical Precip.	Only what is in separated proteins
Biological Systems	Excellent	Generator of SS	Removal of organic only	Will process with time Hinder bio process	Required for biomass	Can be designed to remove within limits
Membrane Systems	Partial Cause problems	Excellent MF	Excellent With RO	No - will cause problems	Good with Precip.	Excellent with RO if oxidised

Membrane systems are essentially a filtration process, and as such could be classified as a physical separation system. However, membranes are a specialist area that is usually applied to wastewater treatment in the final stages to provide very high quality water and as such are in a class of their own.

As can be seen from Figure 13, each process class has particular strengths, and within each process class individual technologies will be deemed suitable depending on the wastewater contaminant strength, flow rate and end use. **There are no single technologies suitable across the whole range of effluent types.**

It is emphasised that deciding which combination of processes is the most suitable for a particular effluent stream is best determined using data obtained from on-site test work, effluent stream analysis and what end-use the treated wastewater will be put to.

5.4.3 Details of Individual Technologies

Following are details of the types of unit operations available, their application and the devices used to achieve the desired result.

Figure 14: Details of Physical Unit Operations

Operation	Application	Devices
Screening (Coarse and Fine)	Removal of coarse solids and other debris from untreated wastewater by interception. Material recovery. Removal of small particles	Bar rack Fine screen <6mm Rotary screen
Comminution	In-stream grinding of coarse solids to reduce size	Comminutor, maceration pump
Flow equalisation	Temporary storage of flow to equalise flowrates and mass loadings of BOD and suspended solids	Equalisation tank
Mixing	Blending chemicals with wastewater and for homogenising and maintaining solids in suspension	Rapid mixer, in-line mixer or mixing tank
Flocculation	Promoting the aggregation of small particles into larger particles to enhance their removal by sedimentation or flotation	Flocculator or aggregation tank
Sedimentation	Removal of settleable solids	Primary clarifier, gravity thickener, sedimentation tank.
Flotation	Removal of finely divided suspended solids with low density, thickening of biosolids Removal of oil and grease	Dissolved air flotation (DAF) Induced air flotation (IAF)
Dewatering	Concentration of thickened solids to a dry cake of relatively low moisture content	Belt filter Disk filter Filter press
Aeration	Addition of oxygen to biological processes. Post aeration of treated effluent	Aeration diffuser Mechanical aerator Cascade aerator
Control of volatile organic compounds (VOC)	Removal of volatile and semi-volatile organic compounds from wastewater	Gas stripper Aeration devices
Air stripping	Removal of ammonia, hydrogen sulphide and other gases from wastewater and digester supernatant	Packed tower

Following are the major biological treatment processes used for industrial wastewater treatment.

Figure 15: Details of Biological Treatment Processes

Type	Common Name	Use
Aerobic Processes		
Suspended Growth	Activated sludge Aerated lagoons Aerobic digestion	BOD removal, Nitrification BOD removal, Nitrification Stabilisation, BOD removal
Attached Growth	Rotating biological contactors Moving bed bioreactor (MBBR) Packed bed reactors	BOD removal, Nitrification BOD removal, Nitrification BOD removal, Nitrification
Hybrid (combined)	Membrane bioreactor (MBR)	BOD removal, Nitrification and biomass filtration
Anaerobic Processes		
Suspended Growth	Anaerobic contact processes Anaerobic digestion	BOD removal Stabilisation, solids destruction, pathogen kill
Attached Growth	Anaerobic packed and fluidised bed	BOD removal, waste stabilisation, de-nitrification
Sludge Blanket	Upflow anaerobic sludge blanket (UASB)	BOD removal, especially high strength wastes
Lagoon Processes		
Aerobic Lagoons	Aerobic lagoons	BOD removal
Facultative Lagoons	Facultative lagoons	BOD removal
Anaerobic Lagoons	Anaerobic lagoons	BOD removal, waste stabilisation

The final stages of any wastewater treatment process, where the water is to be reused within the factory, will undoubtedly contain a number of membrane unit operations. The table below shows the general characteristics of membrane processes common to the wastewater treatment industry.

Figure 16: General characteristics of membrane processes

Membrane process	Membrane driving force	Typical separation mechanism	Operating structure (pore size)	Typical operating range, um	Permeate description	Typical constituents removed
Microfiltration	Hydrostatic pressure difference or vacuum in open vessels	Sieve	Macropores (>50nm)	0.08 – 2.0	Water + dissolved solutes	TSS, turbidity, protozoan oocysts and cysts, some bacteria and viruses
Ultrafiltration	Hydrostatic pressure difference	Sieve	Mesopores (2-50nm)	0.005 – 0.2	Water + small molecules	Macromolecules, colloids, most bacteria, some viruses, proteins
Nanofiltration	Hydrostatic pressure difference	Sieve + solution /diffusion + exclusion	Micropores (<2nm)	0.001-0.01	Water + very small molecules, ionic solutes	Small molecules, some hardness, viruses
Reverse Osmosis	Hydrostatic pressure difference	Solution / diffusion + exclusion	Dense (<2nm)	0.0001 – 0.001	Water, very small molecules, ionic solutes	Very small molecules, colour, hardness, sulfates, nitrates, sodium, other ions

5.4.4 Technology Application Limits and Expected Effluent Quality

Each of the technologies mentioned in the previous sections has a particular optimum application and a range of contaminant concentrations that it can operate in. Application details of the main technologies used in abattoirs are presented in Figure 17 below.

Figure 17: Common technology treatment ranges and potential effluent quality

Technology	Contaminants and Limits	Operational Comments	Expected Quality
Screening	Removal of suspended solids. Limits depend on screen size.	Coarse screening not a problem. Finer screens should have loading rates in order of 3-6m3/m2.min. Finer unscreened solids have small mass	Anywhere from 10% to 80% reduction in SS – depending on particle size
Flotation DAF and IAF	Removal SS, TOG and BOD Loading rates of solids of up to 10kg/m2.h using chemical treatment	Chemical conditioning essential for good solids removal. Can precipitate P or proteins and remove as well. BOD reduction equivalent to non-soluble BOD. Turbidity of effluent usually greatly reduced. Need to ensure that oil/water emulsions broken for good TOG removal.	Nominally 85% reduction in SS, 95% reduction in TOG and 20% to 75% reduction in BOD
Anaerobic Biological Treatment	Removal of BOD (COD). Loading rates of 1 to 5.kgCOD/m3.day Solids stabilisation	Lagoons essentially complete mix anaerobic reactor. Suspended growth with no recycle. Hydraulic residence times of 15-30 days. Suitable for wastes with high solids content or extremely high dissolved organics concentration. If methane can be captured and used, carbon offset. Covered lagoons can handle higher solids concentration.	Will depend on residence time and nature of COD. Should get 90% reduction or better.
Aerobic Biological Treatment	BOD removal Depends on rate constant for aerobic flow-through Facultative lagoon removal efficiency cannot be predicted	Facultative lagoon depends on oxygen transfer from atmosphere and very long solids retention time in anaerobic layer. Aerobic flow-through lagoon has sufficient oxygen for biological requirement, but insufficient for complete solids suspension.	Can predict BOD removal from hydraulic retention time and first-order BOD removal rate constant (0.5 – 1.5). Nominally 80% to 90% of BOD.
Membrane Filtration	Flux rates (L/m2.d) MF 405-1600 UF 405-815 NF 200-815 RO 320-490	Need to consider operating pressure as well, eg: MF operates at 7-100kPa, while RO operates at 850-7000 kPa. Membrane systems cannot tolerate oil and grease. Scaling is a big issue with RO. Operating at acidic pH much better than high alkaline.	Product recovery for various membrane processes MF 94-98% UF 70-80% NF 80-85% RO 70-85%

5.4.5 Examples of Potential Treatment Processes on Individual Streams

Historically the dominant biological processes in the abattoir industry have been the lagoon processes. The reasons for this are abundant land, cheapness of construction and distance from residential / commercial areas. With the focus on water reuse, the treatment of individual streams from inside the factory necessitates a different way of approaching the treatment of abattoir wastewater. Lower flows and less contaminated streams need to be treated individually to yield high quality water, and not be sent to a large end-of-pipe lagoon treatment system. Where lagoons exist, the technology is available to take the final effluent and further process to yield high quality water

Section 3.6 gives example "generic" effluent characteristics from a study in which the suitability of various streams was examined for membrane processing. The streams were stickwater, steriliser and hand wash water, combined plant effluent.

1. Stickwater – This stream is totally unsuitable for membrane treatment as it contains a very high proportion of oil and grease. The temperature would not be a problem for ceramic membranes, but the effluent would still contain sufficient BOD and salts to be unsuitable for reuse. However, the effluent does contain two important resources, ie the residual heat and the very high calorific value of the contaminants. The obvious treatment process for the stickwater would be to capture some of the residual heat, by passing through specially designed heat exchangers, to pre-heat incoming water and in doing so save energy and enable the next biological stage to operate effectively. After cooling, the stickwater could then be treated in an enclosed anaerobic reactor so the methane gas could be collected and reused in the factory; saving gas and accumulating carbon credits.
2. Steriliser and hand wash water – Temperature is a problem for standard membrane technology, but the low level of contaminants in the steriliser water make the water suitable for reuse in non-sterile applications. Simple filtering through a fine filter, such as a 5 micron continuous filter with automatic backwash, then additional disinfection to allow storage for a day, would probably be sufficient. Again, heat recovery to pre-heat incoming water would be worthwhile. The high temperature of steriliser water is of course advantageous in pathogen control; ongoing immediate reuse back into the steriliser process following filtration would remove the problems associated with storage.
3. Plant effluent – This is a high flow, low contamination application. The level of contamination would suggest an aerobic process, with an anoxic phase for the de-nitrification of the wastewater. Existing aerobic lagoons could be converted, or MBBR or MBR technology could be adopted. If a carefully controlled aerobic process was used, to provide very low BOD, ie: <10 mg/L, then an MF/RO system could then be used to provide very high quality water for reuse in all parts of the factory.

The previous examples are only a small sample of potential individual stream treatments that are possible within an abattoir. Like all treatment processes, there are economic payback periods that may be as little as a few months up to many years, even decades. However, the future of manufacturing will depend on the availability and security of a water supply and the sustainability of the process in terms of energy usage. The introduction in the near future of a carbon tax, the current shortage of water in many locations and the rapidly rising cost of energy will force many facilities to rethink how they treat and handle their wastewater.

6 Reuse and recycle applications implemented in Australia

There are a variety of sources describing what reuse and recycle applications can and have been applied in Australia. This includes what AQIS has advised can be done to reduce water usage in abattoirs, including through recycling and reuse practices; and examples of what has previously been done, in terms of the potential to change particular practices, and in the examination of particular abattoirs where changes have been made.

6.1 AQIS position on water usage reduction

It is recognised by AQIS that there is an expectation that the Australian meat processing industry will make water usage efficiencies. This is expressed through the recent meat notice which examines reuse and recycled water applications in abattoirs.

There has previously been a widespread perception that virtually any water reuse and recycling would be unacceptable to export meat production. The following example summarises this:

> *"Strict regulations and food safety standards, such as the EU international standards that specifically affect export facilities, prohibit the reuse of water even for non-product contact areas such as stockyard wash down. The use of potable water and non-potable water in export abattoirs is controlled rigidly by the Export Meat Orders. They stipulate that there must be two separate plumbing systems for potable and non-potable water... It is highly unlikely that overseas consumer countries, particularly Japan and the USA, will approve the direct or indirect use of recycled water in food plants."* (MLA, 2007).

AQIS is in ongoing contact with regulatory agencies in Australia's export meat markets regarding the use of recycled and reuse water in abattoirs, and has incorporated their positions into the draft meat notice (AQIS, 2008).

6.2 Identification of processes suitable for recycled or reuse water

The general areas identified as most suitable for recycled water use have been previously described (MLA, 2007) as follows:

General site operations
- Cooling tower makeup
- Boiler makeup
- Outdoor paved area cleaning
- Watering of landscaped areas
- Cattle truck washing

Abattoir operation
- Stockyard wash down
- Inedible offal processing
- Cleaning around wastewater treatment plants

- Cleaning sprays for screens at wastewater treatment plants
- Initial washing of cattle prior to slaughter (followed by potable water wash)

Potential non-potable recycled water uses are summarised by AQIS (2008) as:

- Steam production (not for meat product contact)
- Fire control
- Yard cleaning
- Animal washing (other than final wash)
- Other similar purposes
- Other circumstances with no risk of water contact with or contamination of meat products

Several examples of reuse processes already approved by AQIS in specific instances (AQIS, 2008) have been noted earlier (see Section 4.4 Water quality regulatory requirements). It is also noted that the list of AQIS-approved processes is expected to grow, following successful validation and implementation by abattoirs.

MLA (2002) lists several combinations of wastewater streams which may be suitable for reuse, along with areas where water could be reused. This is based on the quantities of water involved, and the quality requirements of the downstream process (see examples below).

Figure 18: Example matching of wastewater generation with subsequent reuse areas

Potential source water (kL produced / day)	Potential area of reuse (kL used / day)
Freezer defrost (~5)	Cooling tower makeup (~45)
Knife and equipment sterilisers (~120)	Pig scald tanks (~20kL), Initial stock washing (~100)
Cooling water from pig singeing oven (~20)	Pig dehairing, scaping, brushing (~20)
Handwash basins (~75)	Rendering material conveyance chutes (~5), Sprays on trommel screens (~60)
Carcase wash (~60), Viscera and bleed table wash (~75), Edible offal wash water (~30)	Rendering plant washdown (~8), Odour scrubbers (~5), stockyard washing (~75), Truck washing (~5)
Head wash (~5)	Gut washing (~60)

This example illustrates that reuse of water on site may well be feasible, where effluent quantities and qualities produced can be appropriately matched to the recycled water quality and quantities required. The water quality required for the identified areas of reuse in Figure 18 would in all cases not be potable.

6.3 Cost-benefit analysis of recycled and reuse water

The quantities of water required for plant applications are heavily influenced by site-specific water efficiency measures. A wide variety of water reduction measures and case studies are described in MLA (2002), along with estimations of indicative capital costs, the water savings achievable, and the capital pay-back periods for implementing such measures. Several of these measures may only be suitable for domestic plants, due to particular requirements for export facilities. The described measures are listed here along with the estimated efficiency savings; the calculations are based on assumptions which are detailed in the original report.

Figure 19: Example water savings and pay-back times of eco-efficiency measures

Measure	Capital cost ($)	Water savings (kL/day)	Pay-back
Fitting efficient spray nozzles	~5,000	~55	3-4 months
Centralised control of water supplies	~10,000	~5	3-6 years
Minimising receipt of very dirty stock	Nil	Up to 10	Immediate
Avoid under-utilising spray capacity	Up to 10,000	Up to 35	<1 year
De-dagging to avoid stock washing	~20,000	~95	<1 year
Dry cleaning manure before washing	Minimal	~25	Immediate
Suspended mesh flooring	Up to 100,000	~100	2.5-4 years
Intermittent flow viscera table spray	Up to 7,000	~30	3-7 months
Minimum flow setting for table spray	~3,000	~12	7 months
Chlorinated detergent table cleaning	Minimal	Up to 75	Immediate
Efficient continuous flow sterilisers	Up to 20,000	~42	<1 year
Flow control of continuous flow sterilisers	~5,000	~30	2-5 months
Sensor controlled auto carcase washing	~5,000	~8	1.5 years
Water spray on splitting saws	~5,000	~20	<1 year
Controlled cooling water breaking saws	~1,000	~0.5	5 years
Alternative pig scalding systems	Very high	1-2	Never
Dry dumping of paunch contents	Up to 20,000	44	0.5-1 year
Water efficient tripe & bible washing	~5,000	~13	<1 year
Limiting water use in casing washing	~1,000	~12	3 months
Water efficient gut washing systems	Minimal	~24	<1 year
On/off control of flow	~2,000	~6	10 months
Automatic offal spray washers	~40,000	~15	7 years
Improved dry cleaning before wash down	Minimal	~30	Immediate
High pressure ring main for cleaning	~50,000	~50	1.5-2.5 years
Efficient mechanical washers	~25,000	~30	2 years
Floor cleaning machines	~10,000	<10	3 years
Automatic controls for hand washes	~10,000	~12	1-2 years
Maximising condensate recovery	~5,000	~20	4 months
Probe-triggered cooling tower blowdown	~5,000	~5	2 years
Reuse of clean wastewater streams	Up to 200,000	Up to 400	0.5-1.5 years
Rainwater harvesting	Up to 20,000	Variable	Variable

Some applications resulting in the beneficial utilisation of wastewater are also noted in MLA (2002); including crop production, forestry and land rehabilitation, and aquaculture.

An increasingly important cost-benefit consideration for water usage reduction and recycling is that of water security; provided by an alternative water supply or through demand reduction. Abattoirs in some areas of Australia are facing dramatic reductions in their historic water allocations. Without recycling or water usage reduction, the obvious response to this is reduced production, which has very substantial associated costs to any business.

The need for water security is widely recognised in the meat industry, but it is not often quantified and included in cost-benefit analyses of reuse possibilities of abattoir processes. For example, a recent analysis done under an MLA-funded study (MTU, 2005) examined several reuse options to consider their economic viability, and calculated the required payback period for each option. The results are summarised below.

Figure 20: Example payback periods of water reuse measures

Reuse option	Payback period (years)
Steriliser water reused in yards	5.5
Viscera table reused on table or on paunch contents	3.5
Reuse of steriliser and hand wash waste	4.9
Distillation technology to treat steriliser and hand wash water	>15
Edible offal wash water reused as non-potable supply	3.9
Membrane treatment of final effluent	10.9

This study concluded that none of these reuse options were particularly financially attractive. However, it also noted that it was assumed that abundant potable water was available to the processor, and that the purchase cost of that potable water averaged at $0.75; and that these assumptions would not apply in many circumstances.

A major factor influencing water security and the attractiveness of water recycling is the price of potable water. This subject has been examined for urban water supplies by a recent CSIRO report (CSIRO, 2006) with the aim of helping governments and other water managers to plan to cope with water scarcity challenges. Modelling was performed with different assumptions as to the actions taken to improve urban water security, so as to project water prices in 2032. Four scenarios were modelled, with increasing amounts of action (including water efficiency, water trading between urban and rural Australia, desalination, urban recycling, inter-regional migration to favour development of smaller cities). The estimated mean urban “shadow” prices in 2032 (where supply is equated with demand) are summarised below.

Figure 21: Modelled future shadow water prices in Australian urban centres

City	Current water price (per kL)	Modelled shadow water price in 2032 (per kL)
Sydney	$1.36	$2.62 to $8.09
Melbourne	$1.17	$1.51 to $5.96
Brisbane-Moreton	$1.27	$2.25 to $10.51
Adelaide	$1.30	$1.42 to $1.70
Perth	$1.12	$3.90 to $11.40
ACT	$1.11	$1.45 to $3.23

As can be seen, there is substantial regional variation in projected water prices, and the potential for very substantial price rises in areas particularly affected by water scarcity. This emphasises the need to incorporate water security into cost-benefit analyses.

6.4 Case studies of water usage reductions in Australia

There are many plant-specific examples of applications where water use reduction or recycling/reuse has been implemented in Australian meat processing. The following case studies are some examples for which information has been compiled:

6.4.1 Smart Water Fund project: KR Castlemaine

KR Castlemaine reviewed its abattoir processes at its Castlemaine plant as a Smart Water project (Smart Water Fund, 2007). Dehairing of pig carcases was identified as using large amounts of potable water and producing large amounts of wastewater. A feasibility study concluded that by filtering and reusing the dehairing wastewater, the process could reduce potable water usage by up to 8ML of water per year, and substantially reduce energy requirements for process water heating.

6.4.2 Pollution loads in wastewater streams at the Wagga Wagga abattoir (PIP.012)

The Wagga Wagga abattoir averaged potable water use of 2200kL/day (8.6 kL per tHSCW); and also had some reclaimed water input (total 11.6 kL/tHSCW). Altogether, six primary waste streams were characterised in addition to overall red and green streams (Johns, 2001). Several were identified to focus on elimination and/or separate treatment if cost-effective means could be found to do so. A new DAF unit was installed to improve plant wastewater for discharge.

6.4.3 Water audit and reduction at AMH Toowoomba (PIP.134)

An audit was performed at AMH Toowoomba (MLA, 2004d), with the aim of identifying water usage rates and areas where further savings could be made. A water mass balance was performed, using existing meters, a portable ultrasonic flowmeter, and a bucket and stopwatch; with the top 14 facility water uses identified and measured. Facility water use was measured at 1.95 ML per production day. This project made five major recommendations, which together would save 1.3 ML per week, or 13% of water usage at the time of the audit.

6.4.4 Water audit at Fletcher, Dubbo (PIP.134)

A student project was performed at this Dubbo abattoir (Coughlan, 2006), auditing water usage and identifying areas where further savings could be made. Most (73%) of the plant water usage was sourced from river water; the report recommended that the remaining water (currently town water) could also be sourced from the river, saving $120K per year. Also identified were potential water use savings of 67 ML per year, with a payback of <12 months.

6.4.5 Wastewater audit (PIP.134)

Another study reviewed the effectiveness of a facility wastewater treatment system, analysing all the major waste streams and suggesting reduction and reuse strategies (MLA, 2004b). This involved the measurement of flows and COD in wastewater inputs, and outputs from the facility Save-all, DAF, anaerobic, aerobic and maturation lagoons. Several outcomes resulted from this audit; including repositioning of the DAF to more effectively reduce COD, and redirection of effluent to reduce the loading on the wastewater treatment plant.

6.4.6 Potential for reuse of low contamination abattoir effluent (PIP.010)

This study identified potential processes where reuse water may be able to be used in the facility (MLA, 2004f). This included an attached tannery, which had the advantage of not requiring potable water; this led to this potential reuse being the focus of the project. Other potential options at this facility included stock washing, using 200 to 400 kL per day of medium quality (and ambient temperature) water; stockyard washing, using 50 to 150 kL per day of low quality water; and polisher wash water, using up to 120 kL per day of water of unspecified quality.

Selected streams of wastewater were successfully combined into a reuse water stream to be utilised by the tannery. The cumulative savings in town water and wastewater disposal costs were estimated at $12K/year; capital costs to make these savings were noted as an order of magnitude higher than the savings.

6.4.7 Water use reduction program (PIP.011)

The amount of water required for individual processes can be reduced through examination of practices. An example is the “Water use reduction program” described in PIP.011 (MLA, 2004e), which examined practices in the Frewstal smallstock facility in Stawell. This involved strategic installation of flow meters through the facility, examining water usage of various processes. This identified relatively limited opportunities for reducing water usage, through reducing the number of carcase washes performed. With further examination, it was considered that there would be no detrimental effect on carcase quality if several wash steps were removed, provided macro-contamination was minimised in carcase dressing activities. Reduction in washing resulted in higher levels of micro-contamination, although still well within acceptable levels. The process change was projected as resulting in small water savings, but also substantial labour cost savings. The project outcomes were eventually not implemented at the site due to conversion of the slaughter line to a different dressing procedure. However, it was recommended that other smallstock facilities trying to reduce water usage and wastewater discharge review the project information, noting that monetary savings were obtainable.

This paper demonstrated that some water use practices may not be part of processing because they result in a better product, but instead because that practice has been historically introduced and stayed as part of the process.

6.4.8 Collection of paunch contents for composting (PIP.134)

Segregation of particular wastes can substantially change the quantity and quality of effluent derived from abattoir processes. An example of this can be seen in PIP.134 “Collecting paunch contents for composting” (MLA, 2004); which had the aim of finding an engineering solution to remove solid and liquid paunch contents at source; reducing the paunch processing water requirements, the facility wastewater treatment requirements, and recovering some value of the paunch contents as compost material. A scheme was costed using pumps, pipes, augers and tankers to remove paunch material from the plant, and transport it to the composting site. It was estimated that this scheme would reduce trade waste COD by 25%, and recommendations were made to reduce water consumption during paunch processing.

6.4.9 Water saving work practices

A substantial literature review examining potential water saving work practices and technologies in Australia and elsewhere was performed as part of an efficiency study at a large Australian abattoir (Alliance, 2001). The review describes effective water utilisation practices in abattoirs, including processes such as material transfer, carcase washing, offal processing, hot water generation, defrosting, cleaning, recycling and reuse, dual reticulation of potable water, and monitoring of water usage. This review was performed prior to performing a comprehensive audit of facility water use, and validation of some alternative wash practices.

6.4.10 Water balance at ACC (PIP.134)

Another MLA study was given the task of documenting water use profiles in the ACC Brisbane facility (MLA, 2004c). A process flow sheet was drawn, splitting the site into over 50 major streams, which were then examined using an ultrasonic flowmeter and data loggers. This resulted in a much more complete water balance than had previously been attained, enabling a reduction of weekend stockyard water usage of 1 ML per year, the fitting of flow restrictors to sterilisers resulting in a water saving of 48kL per day, and the identification of other potential savings.

6.5 Abattoir usage of recycled municipal wastewater

While not reuse of water within an abattoir, recycled municipal wastewater is becoming an increasingly available option for many industrial purposes in Australia. Where available it is likely to provide an alternative water source which can be used for many abattoir applications.

The Australian Recycled Water Guidelines (ARWG, 2007) note recycled water as having many potential agricultural applications; including frequent use for pasture, fodder and crop irrigation, livestock drinking water, and shed or stockyard wash down. In this context, recycled water is water originally sourced from wastewaters such as sewage, greywater and stormwater, which has then been treated to a standard where it is fit for other uses. Restrictions that are considered include those based on the consideration of pathogens. Many human pathogens are not of significant concern for livestock health, due to the species barrier. There are some exceptions, such as the helminths; *Taenia saginata* and *Taenia solium*, which may be present in human-sourced sewage. Abattoir or saleyard wastes can be a health risk for other livestock, particularly with Bovine Johne's disease caused by *Mycobacterium paratuberculosis*.

Figure 22: Stock diseases caused by contaminated feed water

Taenia saginata: Also known as *Cysticercus bovis* in cattle, which are an intermediate host for this parasite, causing “beef measles”. Has human health and economic risks. This pathogen can be effectively managed by the detention of wastewater in lagoons.

Taenia solium: Pig tapeworm, can cause neurocysticercosis in humans (severe neurological disease). Australian incidence is extremely low; however the management approach has been to prohibit all sewage-derived recycled water for fodder or drinking water for pigs due to disease severity, and it is recommended that this approach be continued.

Bovine Johne’s: Fatal wasting disease in cattle, caused by *Mycobacterium paratuberculosis*. Cattle susceptible when <12 months of age, although manifestation of disease can take several years. Pathogen can be present in wastewater from animal sources such as derived from abattoirs, and can survive for up to 12 months in moist or wet areas.

Modelling of livestock health risks associated with recycled water is limited by the absence of dose-response data for animal infection. Therefore water quality objectives cannot be derived using quantitative risk assessment. The Guidelines propose that the specific controls traditionally used by the livestock industry continue to be used, as they have been effective.

The Guidelines (ARWG, 2007) also note treatment and water quality requirements for recycled water used for livestock drinking water and dairy shed wash down. The indicative treatment processes for these applications include secondary treatment with helminth reduction (>25 days of lagoon detention or an equivalent filtration process) and disinfection; or primary treatment with >50 days of lagoon detention. On-site preventative measures include preventing consumption by cattle under 12 months of age if the source contains animal waste, and prevention of wash down of milking machinery with recycled water. Water quality objectives include a soluble BOD_5 of <20 mg/L, SS of <30 mg/L, maintenance of a chlorine residual or the use of UV dosing, and *E.coli* concentration of <100 CFU/100mL.

7 Risk assessment of recycling and reuse activities

The objective of this section is to recommend an approach to producing a risk assessment that would meet international regulatory expectations for accepting possible recycling or reuse applications.

7.1 Hazard identification

An essential part of any risk assessment is the identification of relevant hazards. In the case of recycling or reuse of abattoir wastewaters, the expected groups of hazards can be grouped as microbiological (pathogens and spoilage organisms), chemical ("micropollutants" such as disinfection by-products and hormones), physical (macrocontaminants), and regulatory. Many of the hazards associated with recycling of municipal sewage are not relevant to the recycling of abattoir wastewaters, such as pesticides and organic chemicals. The risk levels for chemicals in the meat industry have previously been found to be negligible (MLA, 2003b), even using worst-case scenarios. The predominant risks appear to be associated with microbiological pathogens.

7.2 Quantitative risk assessment

Of substantial importance for risk assessment in this instance is that it is quantitative, where possible. Quantification of risk in source waters, of the target level of risk in recycled waters, and of the effects of treatment allows the level of treatment and subsequent uses of recycled water to be defined. This is very significant; if treatment is insufficient then real risks are not adequately addressed, potentially resulting in severe public health and financial consequences; if over-treatment is required or performed, then water recycling can become financially unattractive and result in less water recycling for abattoir processes. Risk quantification for public health purposes is necessarily conservative, so as to allow safety margins and for limitations of information. However, if the assessment process is overly conservative, then risk mitigation measures can become so onerous and expensive as to again unnecessarily restrict where recycling is performed. Consequently, the quantitative accuracy of risk information is important, as is the use of a risk assessment framework which is able to incorporate that information and be rigorous enough to satisfy the expectations of international regulation.

7.3 Previous risk assessments

Microbial risks associated with meat processing have previously been identified and quantitatively assessed (MLA, 2003); with operational steps reviewed in detail to identify sources of contaminated waste streams, and the development of a model to track pathogen transport through the critical stages of meat processing. This information could be used to identify the relevant pathogen hazards that present a risk to recycling, and to define the expected concentration ranges of those pathogens in the different waste streams to be utilised as source water in recycling. Fifty-two waterborne and airborne pathogens were considered in this study, with six selected for further study due to their relevance to the meat industry and potential risk to human health. These included *Escherichia coli*, *Salmonella* spp., *Campylobacter jejuni*, *Listeria monocytogenes*, *Coxiella burnetii*, and *Cryptosporidium parvum*. The processing steps considered in the study included livestock yard outputs, carcase processing, hide processing, and offal handling; and the effects of treatments including rendering, composting, and wastewater treatment processes.

This study also considers the difficulty of modelling dose response of pathogens in a human population; the accuracy of such information in part determines the accuracy of the risk assessment as a whole. Dose response has been modelled with the assumption that one organism can cause infection; this conservative approach is often used in quantitative risk assessment when dose response information is not available. This study also made several recommendations for future work, of which several are directly relevant for quantitative risk assessment of water recycling; including investigation of site-specific features including waste treatment protocols, attempting to calibrate the risk model with actual statistics on human illness, and consideration of the seriousness of illness to the human population caused by exposure to each pathogen.

The risks associated with foodborne hazards in the Australian meat processing industry have been previously characterised in a comprehensive manner (MLA, 2003b). The risk assessment performed in this study was qualitative, so as to produce a risk ranking of the various hazards to reflect priorities arising from the public health record, and suggest the most appropriate targets for risk management strategies. The software tool used in this assessment (Risk Ranger) uses established principles of food safety risk assessment – probability of exposure to a food borne hazard, the magnitude of hazard when present, and the probability and severity of outcomes that might arise from that level and frequency of exposure. The inputs to the tool include qualitative statements and/or quantitative data. If Risk Ranger is familiar to the meat processing industry and in widespread use, it could be adapted to assessing risks associated with the reuse and recycling of water. This may not satisfy international expectations of risk assessment for all applications, but it could be of use in screening potential source wastewaters, treatments, and applications; so as to suggest suitability and direct more quantitative further risk assessment.

Of interest is the examination of potential BSE spread through various practices in the meat industry; while this is not of current concern in Australia, it is internationally the subject of much regulatory oversight. The potential for spread of BSE via abattoir wastewater in Australia has been previously examined (Quinn and Fabiansson, 2001). This report considered a worst-case scenario of abattoir effluent used for irrigation of pasture, and consequently reinfecting other grazing cattle. This yielded a daily intake of about 320 times less than the ID50 dose (ingestion of 0.1g affected nervous tissue) for infection, with the suggestion that a safety factor of 100 times was often considered adequate in quantitative risk assessment. Abattoir effluent was deemed an unlikely BSE propagation route, even when allowing general grazing of effluent-irrigated areas. One reference cited noted that rendering inactivated at least 98% of BSE infectivity. The risk to humans of contracting BSE from abattoir effluent was considered insignificant, and was not analysed.

7.4 The national approach to recycled water risk assessment

The Australian Water Recycling Guidelines (ARWG, 2006) assess risk in a quantitative way, as part of the process of managing those risks. These guidelines note that the traditional approach to identifying tolerable risk has been to define maximum levels of disease or infection. However, this approach fails to consider the varying severity of outcomes associated with different hazards. To overcome this shortcoming, severity can be measured through the use of Disability Adjusted Life Years, or DALYs. These have been used extensively by agencies such as the World Health

Organisation to assess disease burdens and priorities associated with a broad range of environmental hazards. The basic principle of the DALY is to weight health impacts in terms of severity, multiplied by the duration of effect and by the number of people affected. The duration of effect includes the years of life lost (YLL) and the years lived with a disability or illness (YLD). DALYs provide a means of quantifying the public health impacts of a particular hazard; with the ARWG adopting the level of 10^{-6} DALYs per person per year as an acceptable risk threshold, consistent with the approach taken by the World Health Organisation.

The ARWG consider that the monitoring of all pathogens which may be present in recycled water is impractical. A more feasible approach is through the use of reference pathogens, where representatives of each of the major groups of organisms (bacteria, viruses, protozoa, helminths) for which relevant information is available (concentrations in source waters, dose-response, and disease burden) are assessed instead. It is likely that many microbiological hazards particular to abattoirs have only limited information in these areas. Suitable reference pathogens are those which present a worst-case combination of high occurrence, high concentration in water to be recycled, high pathogenicity, low removal in treatment, and long survival times in the environment. The guidelines select *Cryptosporidium, Campylobacter*, and rotaviruses-adenoviruses as suitable reference pathogens for general application to water recycling risk assessment. The reference pathogens are then used in assessment of the intended uses and associated exposures to the recycled water, and the expected removal of risk through use of treatment processes and other mitigation measures.

Another aspect of the ARWG relevant to risk assessment is the provision of monitoring requirements, so as to ensure that assumptions made in the initial assessment of risk are acceptable. Such monitoring ensures that treatment processes are validated, and that operational performance is subsequently verified.

The quantitative risk assessment approach taken in the ARWG can be extended to incorporate pathogen hazards particular to the meat processing industry which may be relevant to the recycling of abattoir wastewaters, such as *Coxiella burnetii*. This could be done using information already generated by the meat industry regarding these hazards.

The AWRG risk assessment approach discourages use of generic classes of recycled water as being recommended for generic end uses, and instead focuses on risk assessment of particular applications. Guidance for the meat industry could be provided by a generic qualitative risk assessment of the use of recycled water for particular applications. For example, the risk of human pathogen transmission to meat products resulting from the cleaning of stockyards with recycled water could be regarded as being of “Rare” likelihood and resulting in “Minor” consequences (due to subsequent handling); giving a qualitative risk estimation of “Low”.

7.5 International regulatory expectations

As noted in Section 4.4 (water quality regulatory requirements), the approach to recycled and reused water taken in the draft AQIS meat notice (AQIS, 2008) has taken into account the requirements for recycled and reuse water used by our trading partners. In general, the regulatory bodies of export countries are satisfied if AQIS, as the Australian export regulator, allow the inclusion of particular water applications at particular facilities.

Internationally, it is becoming increasingly recognised that the food industry is being forced to consider more efficient use of water and alternative water sources, and the necessity of considering water quality in terms of its fitness for purpose (ILSI, 2008). The international approach to water quality in food production is quite compatible to that taken in the Australian Recycled Water Guidelines – hazard identification, assessment of the risks posed by those hazards, and identification of ways of controlling those risks to levels defined by national and industry standards.

7.6 Recommendations

- Develop a risk assessment framework which is compatible with the approach taken in the Australian Recycled Water Guidelines (ARWG), as described above in Section 7.4 (The national approach to recycled water risk assessment).

- The reference pathogens used for risk assessment should be relevant to the industry. It is unlikely that human viral pathogens will be relevant to risk assessment of water recycling in an abattoir. *Campylobacter* is used in the Guidelines as a bacterial reference pathogen for municipal recycling. This organism may be relevant to some parts of the meat processing industry, such as poultry processing, and should be used when applied to that situation. In contrast, *Salmonella* would be a more relevant bacterial reference pathogen to the red meat processing industry, and would be more applicable for risk assessments in that area. *Cryptosporidium* would be a relevant protozoan reference pathogen for the industry. It also generally serves as a helminth reference pathogen in the ARWG, although a specific helminth reference pathogen such as *Ascaris* or *Taenia* could be more applicable for some recycled water uses.

- Utilise the existing qualitative risk assessment information available to the meat processing industry (MLA, 2003; MLA, 2003b) to support a more quantitative approach compatible with the ARWG. These references are of particular use in defining what hazards are more or less relevant than what could be expected with municipal wastewater. A standardised generic qualitative risk assessment, of specific end uses of recycled water in abattoirs, could be of use to the industry. Benefits would include the clarification within the industry of what uses would be more acceptable to the industry regulators, and provision of a basis for deciding what quality of recycled water would be acceptable for those end uses.

- International expectations appear to be able to be met should the risk assessment (and subsequent validation and verification processes) met the expectations of AQIS. It is recommended that AQIS continue to be closely involved in the development of a risk management framework for recycled water.

8 Identification of further investigations

The objective of this section is to recommend further investigations which are required for the meat processing sector to take advantage of possible technologies to recycle or reuse effluent.

8.1 Improved benchmarking information

There are wide variations in water use per tonne of carcase weight produced between facilities in Australia. While some variation can be expected from specifics of processing at different facilities (number of animals processed and efficiencies of scale, processing large or small animals, whether on-site rendering is performed or not, whether export requirements involving water usage need to be met), it does not appear to be clearly defined as to why such variation exists. When benchmarking water use, it would seem reasonable to account for the noted specific differences between facilities, both in the equipment used and in the manufacturing processes utilised. This would allow comparison of facilities with similar circumstances, and the comparison of water usage for the particular operations or processes. Such benchmarking can assess water efficiency in a more meaningful fashion.

Additionally, benchmarking has historically concentrated on production efficiency; so wastewater quality information has frequently noted contaminant loadings per unit of production (tHSCW), as opposed to contaminant concentrations and volumes of wastewater. This latter information becomes more important when the wastewater is to be recycled or reused, so it would be beneficial for it to be described in future benchmarking studies.

Many facilities are already undertaking water metering throughout abattoir sites so as to identify water usage for particular process steps. This is advantageous since if usage is not measured then efficiency cannot be determined. Metering can be considered as essential for any facility serious about water efficiency.

8.2 Use of published validations to help wider implementation of innovation

It is worth noting the approach taken in “Water at less than 82°C for sanitising knives in abattoirs – a guide to gaining regulatory approval” (MLA, 2007b); where it was demonstrated that systemic use of two knives with lower temperature sterilisation water gave a hygienic outcome of at least the equivalent to current industry practice, along with cost savings, reduced energy use, and reduced worker injuries. This involved the accumulation of a large body of data at several sites, which serves as a validation of knife cleaning at cooler temperatures. This information was then published as an MLA guide, and in the scientific peer-reviewed literature (Eustace *et al*., 2007). This information can now be used by other establishments, allowing much simpler verification requiring only temperature monitoring and documentation when applied elsewhere. This MLA guide also describes the regulatory points to consider in implementing such approved arrangements. Where effluent recycling or reuse applications are of broad potential use in abattoirs, and where substantial validation data has been accumulated, it is recommended that the MLA produce similar guidance documentation so as to help with the further uptake of such innovations, and ensure that such documentation is readily available to the industry.

8.3 Ongoing capture of innovative ideas

The MLA Eco-Efficiency Manual (MLA, 2002) has provided an excellent range of water efficiency, recycling and reuse ideas, along with a systematic evaluation of the practicality and financial attractiveness of those ideas. There can be expected to be further ideas and examples of innovation as water usage is focused on by the industry. It is recommended that the capture of these ideas and examples to a centralised point be a systematic and ongoing process, and that this information is made readily available to the industry.

8.4 Critical comparison of advanced treatment technologies

There has been substantial progress in some advanced wastewater treatment technologies, which may have made some treatment options more financially attractive for specific applications. As noted in Section 5.4, the different treatment processes available have strengths and weaknesses, so site-specific details will usually determine what the best treatment process combinations are. Some treatment solutions are highly technical and may not be well understood by abattoir operators; anecdotally there have been instances where inappropriate treatment processes have been installed at great expense. It may be beneficial to the industry if a generic cost-benefit analysis is performed for a situation applicable to most facilities, such as the recycling of combined abattoir wastewater of a defined quality and quantity to a potable standard. This could critically compare several commercially-available treatment options, providing guidance on treatment solutions currently available to the industry. This guidance could reference examples of where such treatment has been utilised as case studies.

8.5 Capturing cost and benefit impacts

One of the main obstacles to uptake of wastewater recycling treatment technology has been the long pay-back times identified from cost-benefit analysis. One factor which has infrequently been included in such analyses has been the cost impact of forced reduction in abattoir water input from municipal, surface or ground water supplies. There have been several recent anecdotal examples of local water authorities drastically reducing water allocations to abattoirs, requiring large reductions in what those facilities can process. Water security can be seen as a major benefit of recycling, which should be incorporated into future cost-benefit analyses. To assist in the quantification of this benefit, information on local forced water allocation reductions and the resultant impact on production at affected abattoirs could be compiled and made available to the industry.

Another consideration is that other related costs and benefits are captured in the analysis of water efficiency or recycling schemes, such as the interaction of water and energy costs. This is particularly relevant to abattoirs, which use large amounts of hot water, and for which heat is subsequently often regarded as a waste product rather than a resource to be re-captured and utilised. Such integrated cost-benefit analyses have been performed for the meat industry, but may not always be applied when the feasibility of water schemes are examined in isolation. Consideration of the true range of related costs and benefits through the life cycle of manufacturing processes should be promoted by industry bodies. This is very likely to become a more pressing issue following the introduction of a carbon tax or an emissions trading scheme.

8.6 Training

It is noteworthy that a significant proportion of water usage in a typical abattoir is attributed to the cleaning of the facility. Much of this cleaning may be performed by contract cleaners with little awareness of water conservation. Anecdotally, it may be possible to substantially reduce the amount of water used during cleaning, through ensuring that cleaners have been trained to do their job in a fashion which is economical with water. This has not yet been documented at the time of writing; it is understood that MINTRAC will shortly be performing a project examining potential water savings through this sort of training.

8.7 Regulatory involvement and communication

The AQIS draft meat notice provides several examples for which AQIS has approved reuse applications, and signals that more future examples are expected. Once particular reuse concepts are proven as feasible to AQIS, those concepts can be expected to require less validation when implemented at another site. Communicating what reuse concepts could be applied has been a role of the MLA with previous publications such as the Eco-Efficiency Manual (MLA, 2002); this could be extended by maintaining a regularly updated list of AQIS-approved applications, which is accessible to members of the meat processing industry; or by linking to an AQIS-maintained list of the same.

As noted in this review, there have been previous differences of opinion as to what water practices are regarded as permissible by the industry regulators. Water usage reduction and reuse would benefit from ongoing communication on this issue between senior AQIS staff, the Export Meat Industry Advisory Committee, and the MLA. Such a dialogue would have the advantage of informing AQIS of the technical directions planned by the industry, allowing regulatory input into reuse concepts at a relatively early stage.

8.8 Student studies

The undergraduate student studies investigating water efficiency at different abattoirs appear to have generated substantial useful information for the industry in general, and for the studied facilities in particular. Of particular use is where these studies have examined water usage by different production processes, and identified water savings with immediate payback times. It is recommended that these plant-specific studies continue to be supported, and that the students conducting the investigations and their project advisors are aware of what efficiency gains and recycling and reuse innovations have been possible in other case studies.

Of the existing student study reports, some of the information and data appear to be readily accessible, while others are less so. It may be advantageous to compile the existing information into a description of the student studies to-date. This could be of use to guide and add value to future student studies, and to contribute further to the benchmarking information available to the industry.

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