AMPC
AUSTRALIAN MEAT PROCESSOR CORPORATION

Non-potable water recycling guidebook for red meat processors

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Contents

Useful resources

Prior red meat industry R&D in water recycling and reuse includes

1. AMPC, 2021. *Water Reference Group – Assisting industry in adopting Direct Planned Potable Recycled Water for use in abattoirs*
2. Pype, Doederer, Jensen, Keller, and Ford, 2017. *Strategic evaluation of RD&E opportunities for water reuse and recycling at Australian abattoirs*
3. Han Tng, Zhang, Le-Clech, and Trujillo, 2018. *Technical and economic feasibility of water recycling and energy recovery for red meat processing operations in abattoirs*
4. Gould, 2021. *Services and Waste Insights, Reduction and Optimisation Innovation*
5. Tait, McCabe, Hill, and Marchuk, 2019. *Oakey Beef Exports Water Resource Sustainability*
6. Price, Gaffel, and Prasad, 2017. *Stormwater Management Framework and Good Practice Guidelines for Meat Processing Plants*
7. Pype, Walduck, Goebel, and Jensen, 2017. *Investigating water and wastewater reuse and recycling opportunities: identification and segregation of various waste streams*

Executive summary

The Australian red meat processor industry consumes significant amounts of water to maintain its outstanding food safety record. While AMPC's 2022 Environmental Performance Review demonstrated the sector had reduced water intensity by 8 percent since 2015, those savings have mainly come about through low volume water efficiency practices. However, more can be done in both water efficiency and advanced recycling.

This guidebook was created from AMPC water recycling pilot projects. It guides adoption projects in achieving fit for purpose quality standards (i.e. non-potable Class A). During the pilots, source water characteristics, water treatment train options, process monitoring and management, and end use risks were all subjected to months of rigorous risk assessment and measurement before the required controls were designed and activated for risk mitigation and process validation. Unsurprisingly, these quality processes take time, require staged inputs and verified outputs, and need the assistance of a multi-skilled team across science, processes, chemical engineering, QA, WH&S, and food safety. AMPC is thankful for the participation and help of several plants during this work.

Overview

The process for implementing a non-potable water recycling program in a red meat processing plant should follow the order of:

1. **Assess and test** suitable raw liquid stream(s) composition and volume available for recycling

2. **Review industry** water recycling compliance framework documents for the reuse of treated water in fit for purpose areas of the plant

3. **Design a treatment train** to process these stream(s) to a non-potable Class A recycled water standard

4. Conduct a plant **HACCP assessment** (with reference to the above) for the relevant treatment train and the reuse location

5. **Conduct a plant trial** to demonstrate and validate management controls and project costs and benefits.

Raw liquid stream selection/inlet to water recycling system

In general, raw liquid streams should be selected according to:

- Minimum fats, oils, and grease (FOG) content. These are the most problematic contaminants by far.
- For high total suspended solids (TSS) streams, assess the type of suspended solids. For example, suspended grit, dirt, or paunch are unlikely to be a major issue, but very sticky sludges (i.e. exacerbated by polymer-based chemicals or organics) can quickly become difficult to manage.
- Minimum total dissolved solids (TDS), noting that TDS more than 2,000 – 3,000 ppm is well within manageable levels. Potable water is typically around 300 – 400 ppm or higher.
- Ambient temperature streams are preferable to hotstreams, which will require cooling if not using expensive temperature-resistant filtration membranes as opposed to low-cost polymer membranes.
- No heavy metals (e.g. Cr in tannery effluent).
- Equipment manufacturers will have their own limits on trace elements including free chlorine, iron, and manganese.

To characterise potential streams, take a 500 mL sample and send to your closest NATA-accredited testing laboratory and request the following assays:	**FOG** [mg/L]	**TSS** [mg/L]	**TDS** [mg/L]

Depending on the specific stream, testing may also be require for:	**Free Cl** [mg/L]	**NH_3** [mg/L]	**Fe or Cr** and other heavy metals [mg/L]

Typical qualities of red meat processing plant wastewaters

Individual sites will give variable results, but the following table offers a guide to typical qualities to shortlist streams for investigation.

1. Best Choice

	FOG mg/L	**TSS** mg/L	**TDS** mg/L	**Comment**
Hand wash water	11	5.2 – 24	80 – 280	Combination of handwash, knife sterilisation, viscera tray rinse water.
Steriliser water	20 – 130	3.0 – 88	120 – 510	Combination of handwash/steriliser, pneumatic neck cutter steriliser. If possible, segregate lower FOG streams.
Viscera table effluent	24	<1 – 84	130 – 180	Some expected variation along viscera table, increase of suspended solids and FOGs in particular.
Primary cattle wash	<10	57 – 320	300 – 740	Hide on, pre-slaughter.
Final carcase wash (hot cut)	16	66	480	Small stock plant.
Boning room (cold cut)	15	50	150	

2. Second choice, still viable

	FOG mg/L	**TSS** mg/L	**TDS** mg/L	**Comment**
Holding pond	61	27 – 58	870 – 990	Post CAL & BNR. This tends to be a variable source as the concentration fluctuates with runoff/evaporation to and from pond
Slaughter floor runoff	31	100	810	Generally high Fe heavy metal content as heme-iron – does not degrade RO membranes in the same way as elemental Fe
Activated sludge SBR effluent	34	180	1,200	Viable feed for a water recycling plant, but consider other sources first.
Paunch press effluent	11	3,700	2,000	High TSS however not sticky or tendency to floc. Viable but consider other sources first.
DAF effluent	16	8.2 – 170	1,200 – 3,700	Confirm if TSS content is from overdosing of floc polymer. Take sample and let settle for 24 hrs, flocs will become evident if present. Very difficult to test and can be a challenge for filtration due to tendency to “clag” membranes. Viable but consider other sources first.

3. Unlikely to be viable

	FOG mg/L	TSS mg/L	TDS mg/L	Comment
Saveall effluent	180	3,800	780	High temperature and high FOG – difficult to manage.
Tannery effluent				High Cr content will destroy membranes, not recommended.
Saveall + Contrashear effluent	330	670	480	Very high FOG content, will be problematic.

To assist in characterising the above streams, the following images were taken of indicative samples. Individual plants may have access to more or fewer raw sources, and there may be variations in quality, so the images are intended to be indicative rather than universally representative. A discussion is given on the characteristics of individual samples with respect to recycling.

In the red streams, common characteristics are the presence of fats, oils, and grease (FOGs) as suspended solids and high nutrient load (BOD). Suspended solids in the red streams tend to float, so passive solid removal technologies such as clarifiers can be designed with top skimming.

The greatest economic benefit of these streams will be first in recovering saleable protein meal and tallow in the rendering plant, followed by recovering biogas where an anaerobic lagoon is in place, and finally in water recycling for reuse.

Salinities of the red streams will generally range from lowest for knife steriliser, hand wash, carcase defrost, and carcase wash, to highest for DAF effluent. The greatest concern with these streams in recycling is the elevated temperatures, generally ranging from 40-65°C. Filtration membrane performance is poor at temperatures above 35°C. The best option for reducing these temperatures is sufficient buffer tank volume and time to normalise to ambient temperature (e.g. overnight). If space for buffering is limited, active cooling can be used in a simple non-contact plate-frame heat exchanger, but this will add cost.

Figure 1

Example "red stream" sub streams. From left to right: knife steriliser, DAF effluent without coagulant dosing, combined kill floor runoff inclusive of hand wash, and kill floor washdown from knocking box.

Figure 2

Example “green stream” sub streams. From left to right: post-DAF, anaerobic CAL, aerobic BNR holding pond water prior to sewer discharge, tripe room effluent (approximately similar to viscera table), and first wash. For subsequent washes prior to slaughter, expect decreasing turbidity, suspended solids, and salinity.

Common characteristics of the green streams are significantly higher suspended solids of a larger particle size, lower FOGs content, high organic carbon BOD, lower nutrients, high pathogen load, and lower temperatures typically at ambient. Green stream suspended solids tend to be larger, making them easier to remove. They also tend to sink, so if taking raw water from a pond, the pump suction pipe should be set at least 0.5m above the bottom of the pond to avoid drawing excessive sludge.

Salinities of the green streams will generally range from lowest for viscera table/tripe room runoff, to highest for final holding pond water. Suspended solids will generally range from lowest in final holding pond, to highest for paunch press and first wash. If aiming to recycle green streams, particular attention should be paid to effective and robust removal of suspended solids and sludges as these are the primary concern.

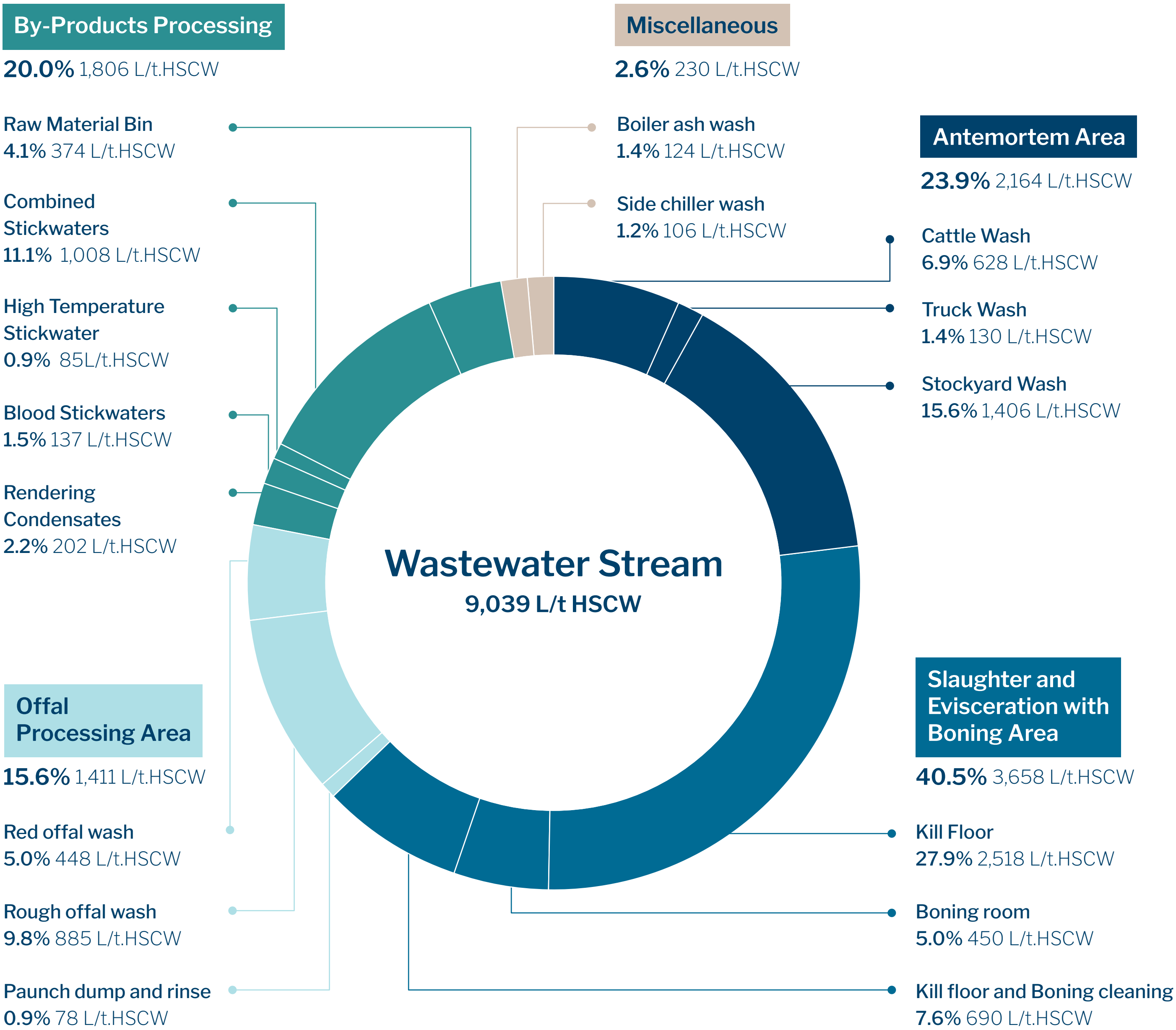
Available volumes

Due to the various combinations of unit operations that comprise wastewater treatment at Australian red meat processing plants, it is difficult to authoritatively quantify the available volumes of the above streams.

Prior AMPC R&D has provided some estimates of wastewater volumes and intensity for typical red meat processing plants from literature[8] as below, but individual plants may differ.

[8] (Tng, Zhang, Le-Clech, & Trujillo – 2021)

Figure 3
Separated red meat processing plant wastewater streams intensity in L/t.HSCW and as a fraction of total.



References

MLA, 2003
Jensen and Batstone, 2012
Jensen and Batstone, 2013
Warnecke et al., 2008
Johns, 2011
Ruiz et al., 1997
Muhirwa et al., 2010
Nakhla et al., 2003
Hansen and West, 1992
Johns, 1995

Some broad recommendations

- Streams further down the treatment process will have more available and consistent volume e.g. a final holding pond will have a larger volume at a stabilised temperature and be more resistant to daily fluctuations compared to the intermittent trickle from a handwash pipe.
- If attractive streams are low in volume or intermittent in supply, consider blending with other similar sources and installing buffer tanks e.g. antemortem, boning, and offal processing areas.
- For hot streams from slaughter floor and rendering, buffer tanks can be used to allow hot fluids to naturally normalise with the ambient temperature without the need for expensive cooling system.
- Check for any time-based fluctuations in the quality of a shortlisted stream e.g. from plant cleaning (including boot and handwash), plant services, and sterilisation at the beginning, end, or changeover of a shift. Fluctuations can be averaged out with buffer tanks.

Technology options for treatment to Class A non-potable standard

A non-potable water recycling plant at a red meat processing plant will typically consist of:

1. Coarse filtration

Achieving >90% TSS removal down to as little as <1 mg/L. Typically achieved by a multimedia filtration (MMF) combination of:

a. Silica of various grades – or sand
b. Ceramic
c. Carbons – anthracite or activated charcoal
d. Gravel
e. Zeolite

2. Ultrafiltration (UF)

Down to 0.04 microns to remove particulates to <0.1 NTU and pathogens <1 CFU/100mL. Membranes range from

a. Polymer – cheapest upfront cost, require more frequent cleaning and replacement. Sensitive to temperature
b. Ceramic – more expensive upfront, not sensitive to temperature
c. Titanium – most expensive upfront cost, much less frequent replacement. Not sensitive to temperature

3. Ion exchange

Can be a more economical removal (compared to RO) of charged compounds e.g. nitrate, nitrite, ammonium etc. Expect >90% exchange efficacy with output concentration of target ion <1 mg/L. A range of selective ion exchange resins exist to target various cations or anions.

4. Reverse osmosis (RO)

High pressure, semi-permeable membrane filtration to remove TDS, viruses, and protozoa. Expected recovery typically 50-70% with output conductivity <100 µS/cm for dirty streams such as pond water, and <10 µS/cm for cleaner streams such as carcase defrost.

5. Additional microbial control barriers

Typical choices are chlorination, ozone dosing, or inline UV disinfection with the most fit for purpose decided by ongoing operating cost (lowest for chlorine), and specific disinfection required.

Current permitted end uses

The AQIS Meat Notice 2008/06 Efficient Use of Water in Export Meat Establishments references AS 4696 Hygienic Production and Transportation of Meat and Meat Products for Human Consumption. AS 4696 Sect 21.6 states that recycled water cannot be used to produce meat and meat products unless it is used for:

(i) Steam production where there is no direct or indirect contact with meat and meat products, fire control, cleaning of yards, washing of animals (other than final wash), and other similar purposes not connected with meat and meat products
(ii) Other circumstances where there is no risk of the water coming into contact with or contaminating meat and meat products.

AS 4696 Sect 21.6 also states *the approved arrangement expressly provides for the use of non-potable water in the circumstances* in which it is used, meaning that any use cases must be added as an approved arrangement with your OPV.

Class A non-potable recycled water can hence be used for the following processes:

- ✓ Stockyard and truck washing
- ✓ Cattle drinking water
- ✓ Amenities and fire control
- ✓ Boiler systems and steam production (no contact with meat)
- ✓ Cooling towers, evaporative condensers/rendering condensers, non-contact heat exchangers
- ✓ Inedible offal/tallow processing
- ✓ Cleaning in place systems not in contact with meat.
- ✓ Noting these limitations, end uses that were demonstrated as part of this project are outlined in Table 1 below.

Table 1
End uses, quality spec, suggested treatment train, and benefits.

1. Implement first*

Yard/truck wash

Quality Specification	Treatment	LCoW $/kL	Benefits
Minimised TSS to prevent pump damage	Screening/coarse filtration to remove TSS	$0.37 – $0.44	• Reduced potable water demand • Reduced trade waste discharge

Primary belly wash

Quality Specification	Treatment	LCoW $/kL	Benefits
Minimised TSS to prevent pump damage	Screening/coarse filtration to remove TSS	$0.37 – $0.44	• Reduced potable water demand • Reduced trade waste discharge

*Safe use of recycled water requires potential health risks to be reduced to levels as low as reasonably practicable, hence consideration of site-specific microbial hazards should be done and mitigated if necessary. In practice, if feedstock contains appreciable microbial content, UF and chlorination should be included in the treatment train before reuse in truck or belly wash.

2. Implement second

Stock drinking "palatable" water

Quality Specification	Treatment	LCoW $/kL	Benefits
From ANZECC 2000 *Australian and New Zealand Guidelines for Fresh and Marine Water Quality vol 3 – Primary Industries – Rationale and Background Information*[10] • Ca <1,000 mg/L • Mg <1,000 mg/L • NO_3 <400 mg/L • NO_2 <30 mg/L • SO_4 <1,000 mg/L • TDS <4,000 mg/L • Non-detectable pathogens	1. Screening/coarse filtration to remove TSS 2. Ion exchange if high levels of nitrate, nitrite, or sulphate 3. Ultrafiltration 1st level of sterilisation 4. Chlorine dosing for microbial validation	$1.0 – $1.21	• Reduced potable water demand • Reduced trade waste discharge

3. Implement third

Refrigeration condensers

Quality Specification	Treatment	LCoW $/kL	Benefits
Refer to specific quality spec from manufacturer; indicative recommended quality spec: • Legionella <10 CFU/mL • Heterotrophs <100,000 CFU/mL • TDS <700 mg/L • Conductivity <1,000 uS/cm • pH 7 – 9 • Alkalinity 70 – 400 mg/L • TSS visually low • Ca hardness <500 mg/L • Cl <250 mg/L	1. Screening/coarse filtration to remove TSS 2. Ion exchange if high levels of nitrate, nitrite, or sulphate 3. Ultrafiltration 1st level of sterilisation 4. Reverse osmosis 2nd level of sterilisation and TDS removal 5. Chlorine dosing for microbial validation	$1.93 – $2.17	• Reduced potable water demand • Reduced cooling tower chemicals consumed from less frequent blowdown – Oxidising biocide – Non-oxidising biocide – pH control – Multifunctional inhibitor • Reduced scale accumulation • Improved heat transfer efficiency • Reduced trade waste discharge

Rendering condensers – no contact with rendered product

Quality Specification	Treatment	LCoW $/kL	Benefits
Refer to specific quality spec from manufacturer; indicative recommended quality spec: • Legionella <10 CFU/mL • Heterotrophs <100,000 CFU/mL • TDS <700 mg/L • Conductivity <1,000 uS/cm • pH 7 – 9 • Alkalinity 70-400 mg/L • TSS visually low • Ca Hardness <500 mg/L • Cl <250 mg/L	1. Screening/coarse filtration to remove TSS 2. Ion exchange if high levels of nitrate, nitrite, or sulphate 3. Ultrafiltration 1st level of sterilisation 4. Reverse osmosis 2nd level of sterilisation and TDS removal 5. Chlorine dosing for microbial validation	$1.93 – $2.17	• Reduced potable water demand • Reduced cooling tower chemicals consumed from less frequent blowdown – Oxidising biocide – Non-oxidising biocide – pH control – Multifunctional inhibitor • Reduced scale accumulation • Improved heat transfer efficiency • Reduced trade waste discharge

4. Implement fourth

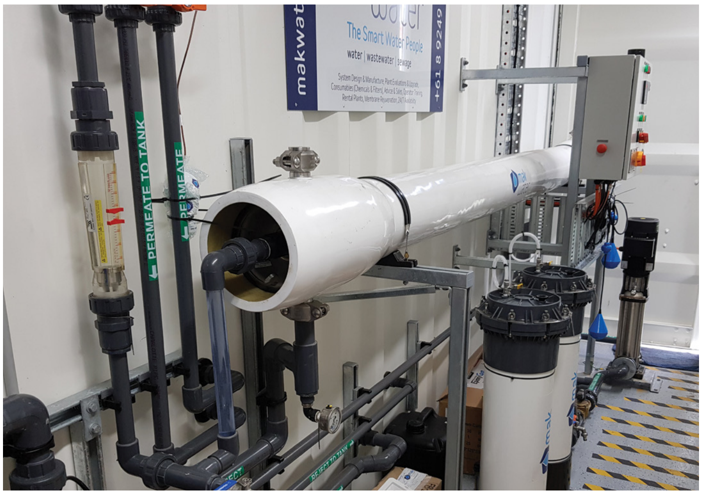
Boiler makeup

Quality Specification	Treatment	LCoW $/kL	Benefits
Refer to specific quality spec from boiler manufacturer; indicative quality spec[11]: • Fe <0.1 mg/L • Ca Hardness <0.3 mg/L • TOC <1 mg/L • FOGs <1 mg/L • pH 7.5 – 10 • Alkalinity <350 mg/L • Conductivity <3,500 uS/cm • TDS <4,000 mg/L	1. Screening/Coarse Filtration to remove TSS 2. Ion Exchange if high levels of nitrate, nitrite, or sulphate 3. Ultrafiltration 1st level of sterilisation 4. Reverse Osmosis 2nd level of sterilisation and TDS removal	$1.93 – $2.17	• Reduced potable water demand • Reduce feedwater treatment chemicals consumed – Softeners – Anti-scalants – Oxygen scavengers – Alkalinity builders • Less frequent blowdown – More boiler uptime – Less fuel consumption • Reduced scale accumulation • Improved heat transfer efficiency • Reduced trade waste discharge

CapEx and Levelised Cost of Water

Indicative CapEx and levelised cost of water (LCoW) for each grade of treatment is shown on the next page. Key assumptions:

- ✓ MMF replaced every five years; UF replaced once per year, RO replaced every two years
- ✓ CIP using citric or acetic acid every two months
- ✓ Anti-scalant replacement every two years
- ✓ Labour/operating staff: 0.05 FTE MMF, additional 0.10 for UF, additional 0.20 FTE for RO
- ✓ RO assumes 50% of the feed volume to permeate (i.e. 50% of the feed exists as waste concentrate, with 50% of the volume being purified RO water).

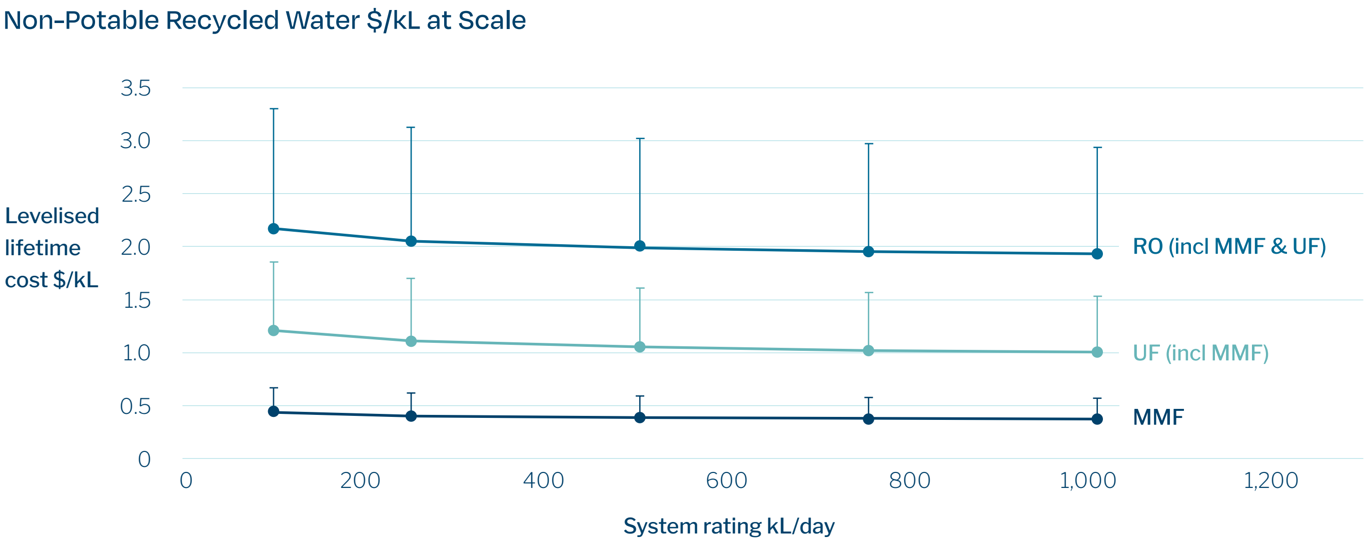


[9] Levelized cost of water over the equipment lifetime inclusive of capital and operating costs of power, labour, maintenance, and chemicals
[10] Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000) – Volume 3 – Chapter 9 – Primary Industries
[11] Characteristics of boiler feedwater – Lenntech

Table 2
Indicative capital costs and LCoWs for each treatment train.

Input feed kL/day	Coarse filtration MMF		Ultrafiltration including MMF		Reverse osmosis including UF & MMF	
	CapEx	LCoW	CapEx	LCoW	CapEx	LCoW
100	$40,000	$0.44	$140,000	$1.21	$160,000	$2.17
250	$80,000	$0.41	$260,000	$1.11	$300,000	$2.05
500	$130,000	$0.39	$430,000	$1.05	$500,000	$1.99
750	$180,000	$0.38	$570,000	$1.02	$660,000	$1.95
1,000	$220,000	$0.37	$700,000	$1.00	$800,000	$1.93

Figure 4
LCoW at scale for MMF, UF, and RO technologies



When assessing the feasibility of a non-potable water recycling scheme for red meat processing plants, it is important to compare the above LCoWs to the current rate paid to your local regional authority for town water and sewerage. For instances where LCoW is cheaper, as in most of the metro and semi-regional plants in the country, this is an economically viable project to undertake. Certain conditions such as operating on bore water or with particularly favourable water tariffs may mean that non-potable water recycling is not viable on a strictly economic basis, though other considerations such as the relationship with the local community and social licence to operate in drought-prone areas remain factors for consideration.

The positive error bars in the above LCoW trend are for the most pessimistic scenario where installed CapEx is 30 percent higher, annual OpEx for power, labour, chemicals, and maintenance is 20 percent higher, and expected recycled water production is 20 percent lower.

Due to the degradation of a membrane over its service life, fouling accumulation, and the variable qualities of red meat processing plant wastewaters, production throughput will trend downwards in between services so depending on the proximity of the estimated LCoW to the current rate paid for town water, it may be prudent to assume a higher value when making investment decisions.

Potential impacts of recycling and reusing water in utility and stock drinking for a 1,000 hpd facility (assumed 2,000 in lairage and 1.3 ML/day incoming potable) are estimated at:

- Stock drinking 100 kL/day (7.7% of potable requirements)
- Refrigeration condensers 110 kL/day or more especially in summer (8.5% of potable requirements)
- Boiler makeup 30 kL/day (2.3% of potable requirements).

Glossary

Alkalinity [mg/L]
Presence of hydroxides, carbonates, and bicarbonates of elements including calcium, magnesium, sodium, potassium, or ammonia in a sample. Commonly used to indicate the hardness of water and hence potential for scale accumulation in boilers, condensers, evaporative coolers etc.

Anions [mg/L]
Dissolved molecules with a net negative charge. Examples include sulphate, phosphate, bicarbonate, and chloride.

BOD [mg/L]
Biological oxygen demand. Measurement of the dissolved oxygen consumed by biological microorganisms in the biochemical oxidation of organic matter. Used to indicate the organic carbon and other nutrient content and hence how much oxygen will be required to stabilise or if an existing process is working effectively.

Cations [mg/L]
Dissolved molecules with a net positive charge. Examples include sodium, magnesium, and calcium.

COD [mg/L]
Chemical oxygen demand. Similar to BOD but also inclusive of dissolved oxygen consumed in non-biological reactions. COD is always greater than BOD.

Conductivity [µS/cm or mS/cm]
Measure of a solution's ability to conduct electricity, dependent on the concentration of anions and cations in the solution. Commonly used to indicate the level of TDS and hence the effectiveness of treatment and potential for scale accumulation in boilers, condensers, evaporative coolers etc. The units "µS/cm" are also routinely written in shorthand as "uS/cm".

CW
Cold water.

FOG [mg/L]
Fats, oils, and greases.

Green streams
Water sources generated from manure and paunch wastes from the emptying of the animal stomach and internal organ processing.

HACCP
Hazard analysis and critical control points.

HW
Hot water.

Microbes
While not the same from a purely biological definition, bacteria, protozoa, and viruses are grouped together here as the treatment steps for removal are the same. Common microbes/pathogens tests that may be typically encountered in export regulations are E. coli, enterococci, clostridium, colony count, and faecal coliforms.

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

TDS [mg/L]
Total dissolved solids – not visible to the naked eye. Related to the conductivity of a solution, but typically handheld TDS metres are unreliable as these measure the conductivity and convert to TDS by multiplying by a factor of 0.6 – 0.8. This approach is reasonable at relatively high TDS of town water for example, but unreliable when measuring purified water by RO. For accurate TDS results, a sample must be sent for lab analysis where the solution is evaporated, and the residual mass of dissolved solids is measured.

TSS [mg/L]
Total suspended solids which are wholly or partially visible to the naked eye. Examples include paunch, dirt, sand or hair in the green streams; and fats and blood colloids in the red streams.

Turbidity [NTU]
A measure of the cloudiness or murkiness of a fluid caused by large numbers of dissolved and suspended solids 0in solution that may or may not be individually visible to the naked eye. Calculated by measuring a solution's ability to refract light.

Volume Units
Typical units are m^3 or kL which both are equal to 1,000 L.
A ML is 1,000 m^3/kL and hence equal to 1 million litres.

WW
Warm water.

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