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A RISK MANAGEMENT FRAMEWORK FOR *TAENIA SAGINATA* EGGS IN RECYCLED WATER TO MINIMISE THE RISK OF CYSTICERCUS BOVIS IN CATTLE

IMPLICATIONS FOR THE PRODUCTION AND USE OF RECYCLED WATER IN AUSTRALIA

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A risk management framework for *Taenia saginata* eggs in recycled water to minimise the risk of Cysticercus *bovis* in cattle

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ABBREVIATIONS

AGWR	Australian Guidelines for Water Recycling
AMPC	Australian Meat Processor Corporation
ASP	Activated Sludge Plant
CB	Cysticercus *bovis*
CBA	CB Animal identification device status
CBP	CB PIC status
CBW	CB Warning
CCP	Critical Control Points
CVO	Chief Veterinary Officer
HACCP	Hazard Analysis and Critical Control Point
HE	Helminth egg
HRT	Hydraulic retention time
ISC	Integrity Systems Company
LRV	Log Reduction Value
LRV_{RE}	Log Reduction Values for Reduction in Exposure
NLIS	National Livestock Identification System
PIC	Property Identification Code
PMI	Post-Mortem Inspection
QA	Quality Assurance
UV	Ultraviolet
WWTP	Wastewater Treatment Plant

ABSTRACT

To use water recycled from sewage (recycled water), the helminth egg from *T. saginata* requires management to minimise the risk of causing Cysticercus *bovis* (CB) in cattle when the egg is ingested. Recent advances in the risk management of helminth eggs in recycled water have allowed a risk management approach to be developed by the cattle production sector and low risk recycled water defined (i.e. fit for the purpose of cattle production).

The approach described here connects the risk-based management systems from the recycled water, cattle production and processing sectors. The recent literature was also reviewed to update methods for achieving the required LRV to provide low risk recycled water. The connection between the two sectors allows improvements and cost savings for both sectors by providing a rational quantitative approach to CB management in cattle where recycled water is used.

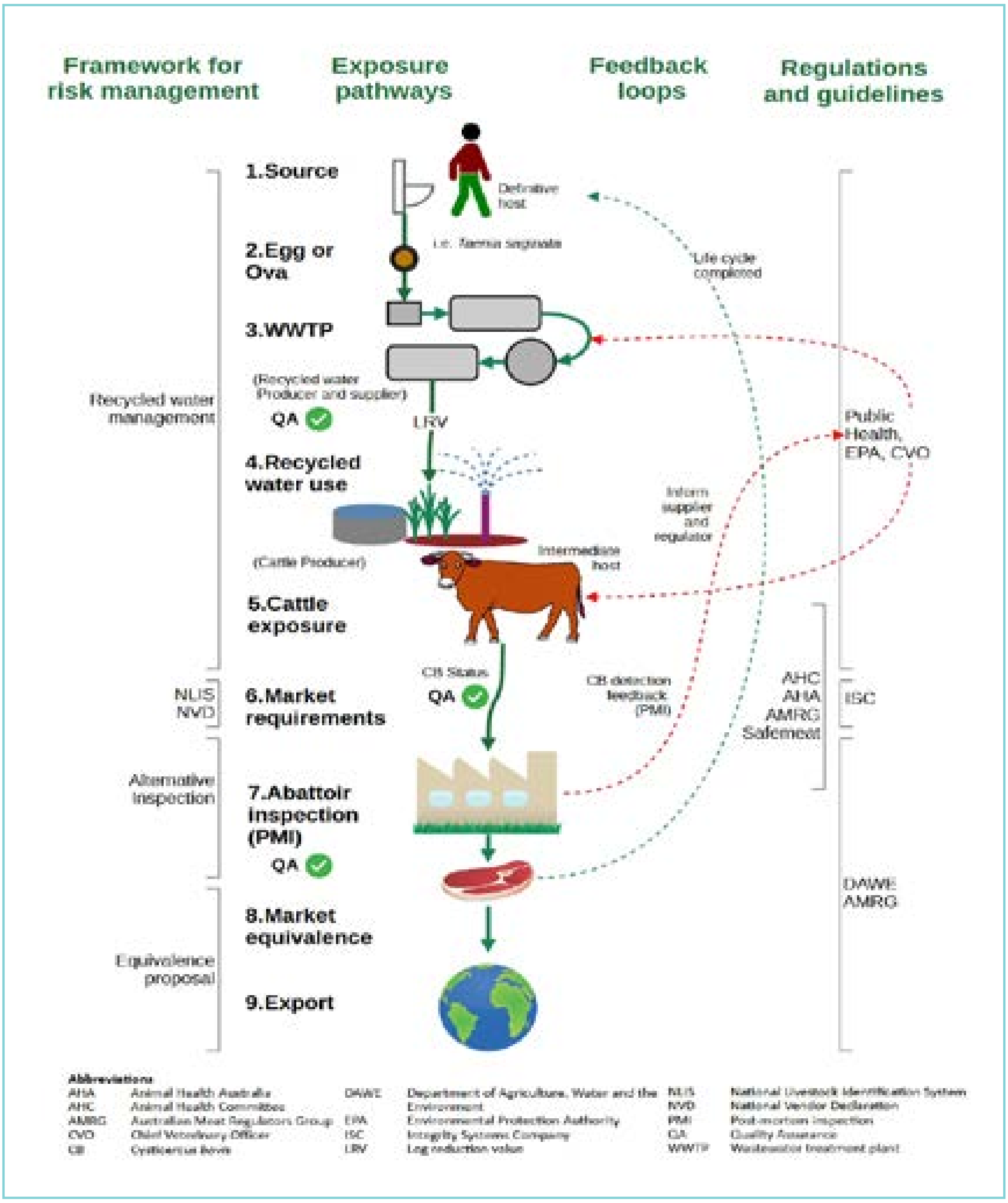

Figure 1: *Taenia saginata* and Cysticercus *bovis* risk management frameworks, exposure pathway, feedback loops and related regulatory authorities (modified from Stevens and Pointon (2022))

INTRODUCTION

Although recycled water is used for the production of a small portion of the beef produced in Australia (approximately 0.7%), this represents a significant number of cattle (180,000) and volume of recycled water (50,000 ML/year) (Stevens and Pointon, 2022). These figures vary considerably depending on the season and stocking rates and could potentially increase if more recycled water is fit for the purpose of cattle husbandry.

One of the associated risks of recycled water use to the Australian meat industry is CB, caused by ingestion of *T. saginata* eggs by cattle, sourced from the faeces of humans infected with the tapeworm *T. saginata* (the human zoonosis known as Taeniasis) (Stevens et al., 2021a). The exposure pathway that closes the life cycle of *T. saginata* involves the exposure of raw or treated sewage (Figure 1) to the intermediate host (cattle), where a cyst infects the animal muscle (meat), which humans can ingest. Thus making *T. saginata* the helminth of interest for animal health, meat quality, and protection of human health (Stevens et al., 2021a). A similar risk is found in pigs. However, due to the severity of the infection (neuro-cysticercosis), the life cycle of *T. solium* is prevented in Australia by excluding pigs from exposure to recycled water (NRMMC et al., 2006).

Recently, meat safety inspection and product integrity in Australia were modernised (AS 2023). The modernisation was enabled by improvements in animal health, the incidence of zoonoses over the past 40 years and the documented concentrations of *T. saginata* in sewage (Pearse et al., 2009; Pointon et al., 2018; Stevens et al., 2021a). An unmanaged meat safety risk in domestic or exported markets did not initiate the modernisation. It was driven by improving inefficiencies in the industry and the possibility of adopting a quantitative risk-based approach to improve meat safety and quality management from paddock to plate (CAC, 2005; FAO, 2019).

Given the complexities discussed above, the risk management of recycled water production, meat production and official meat inspection that underpins market access requires a multidisciplinary approach. Such an approach integrates the risk assessment and management through the various regulations and guidelines (Figure 1).

The aims of this paper are to:

(i) Outline the integration of risk management approaches for CB management used by the Australian:
   a. Water industry's recycled water production (Exposure Pathways 1 to 5, Figure 1). Therefore, linking recycled water quality requirements to those required for the cattle/meat industry.
   b. Food safety authorities (Supported by Safemeat and Livestock Production Assurance programs; Exposure Pathways 5 to 9, Figure 1), including international market equivalence (8) and export requirements (9).

(ii) Recommend control measures for pasture irrigation and fodder production with recycled water that is suitable for cattle production.

(iii) Discuss the implications of this updated risk management approach when using low or high risk recycled water for:
   a. recycled water producers, and
   b. cattle producers using recycled water.

METHOD

Integration of food safety with recycled water quality

The Integrity Systems Company (ISC, 2023) cattle requirements for CB were reviewed, and the appropriate integration with the recycled water producers and users was considered.

Requirements for recycled water use with cattle

The definitions of low and high risk recycled water for exposure of recycled water to cattle by ISC (2023) were reviewed with a recently published risk-based approach for minimising CB risk from recycled water use (Stevens et al., 2017, 2021a, 2021b).

Assessment of the Log Reduction Value (LRV) achieved from common wastewater treatment processes in Australia was summarised from the literature, other than lagoons, which are well documented (Stevens et al., 2017, 2021b). One LRV is an order of magnitude reduction in the concentration – if the Helminth Egg (HE) concentration decreased via a treatment process from 100 to 10 HE/L, this equals a LRV of 1.0.

Similarly, a decrease from 100 to 1.0 HE/L would be a LRV of 2.0, etc. This assessment focused on activated sludge plants (ASP), chlorination, UV and ozone treatments. For ASPs, helminth egg removal across an individual Wastewater Treatment Plant (WWTP) was reviewed and used only where data was considered appropriate quality (i.e. influent concentration where such that the LRV would not be restricted as the HE was not detected (e.g. < 1.0), or the ASP was indicated as very old). Suitable data for the ASP, or primary settling and ASP, were identified for 21 individual WWTPs from 2011 to 2019 (Ben Ayed et al., 2009; Tyagi et al., 2011; Sharafi et al., 2012; Amoah et al., 2018; Sabbahi et al., 2018; Hamaidi-Chergui et al., 2019). These individual data were compared to a recent review where individual data points considered were not made available (Zacharia et al., 2018). Relevant data identified for the LRV of helminth eggs from treatment by chlorination, UV and Ozone dosing were also assessed to summarise the current understanding of these treatments for helminth egg inactivation or removal. Data was considered relevant if the doses described were possible in routine wastewater treatment.

Implications for recycled water and cattle husbandry

The implications for recycled water production and use that would ensure compliance with low risk water were discussed considering the implications for recycled water and cattle producers.

RESULTS AND DISCUSSION

Integration of food safety with recycled water

Due to an improved understanding of the risks recently, the Australian Meat Process Corporation (AMPC) has reassessed the risk to the cattle industry regarding CB, commonly known in the cattle industry as beef measles (Kiermeier et al., 2019; Stevens et al., 2021a, 2021b; Pointon, 2023). Cattle are potentially infected with the cyst of *T. saginata*, which causes CB when the cattle ingest the *T. saginata* egg found in human faeces. Therefore, one potential source is sewage or other water sources containing human faecal material. If this recycled water is not adequately treated to minimise the exposure of the helminth egg to cattle, recycled water use is considered high risk. However, the risk is considered low if the recycled water quality is adequate (ISC, 2023). As part of the reassessment of the risk management arrangements, a CB Risk Management Survey of the Controlling Authorities (seven jurisdictions) for the previous five years was conducted (Pointon, 2023). While detections of carcase abnormalities consistent with CB were infrequently recorded at routine Post-Mortem Inspection (PMI), none tested positive for CB deoxyribonucleic acid by polymerase chain reaction (i.e. CB), consistent with previous findings reported by Pearse et al. (2010). These were typically single cases from a property and did not result in assigning a CB Status following property risk assessments.

Cattle exposed to low risk recycled water are considered as an equivalent risk to cattle that have had no exposure to recycled water and are acceptable for the market (AS, 2023). Routine minimum inspection of low risk cattle at the abattoir requires incision of the heart and observation of masseter muscles, maximising the use of this meat. However, all cattle exposed to high risk recycled water now require a new CB Property Identification Code (PIC) Status identification (ISC, 2023). They also require incision of the masseter muscles and full carcase PMI as per Schedule 2 of the Australian Standard 4696:2023 (AS, 2023).

Where cysts are detected, Schedule 3 of AS 4696:2023 requires trimming and condemning lightly infected material. However, the detection of numerous suspect cysts results in the condemnation of the entire carcase. To reduce the need to routinely incise the masseter muscles of all cattle, industry and government have implemented a risk framework to identify enterprises that use 'high risk' recycled water concerning CB, resulting in high risk cattle.

The Livestock Production Assurance program introduces risk management related to recycled water use to ensure that only cattle from properties using high risk recycled water are subject to full inspection at processing. Identification of possible CB cysts in a carcase will result in Chief Veterinary Officer (CVO) notification in all cases, as CB is notifiable in all jurisdictions (ISC, 2023; Pointon, 2023). The detection of abnormalities consistent with CB in cattle during abattoir PMI is initially reported back to the producer as part of a property risk assessment (Pointon, 2023) and upon confirmation to the recycled water producer and supplier (Pathway 7 Figure 1, red dashed line).

Requirements for recycled water use with cattle

The definition of low and high risk recycled water for pasture irrigation suitable for cattle production

Industry and government have worked to implement a risk management framework for the use of recycled water for livestock grazing to supplement the ISC guidelines and provide the link between recycled water suppliers, users and the cattle production industry.

Concerning *T. saginata* eggs exposure to cattle via recycled water, the ISC (2023) indicates that the cattle production industry defines the risk as follows:

(i) Low and acceptable if the recycled water user demonstrates through the agreement with the supplier that the recycled water is low risk and has been treated to achieve a:
  a. LRV of 4.0 in *T. saginata* egg concentration or equivalent; or
  b. LRV of 3.0 - only if the producer supplies other fresh drinking water to cattle. The recycled water supplier must confirm that the sewage quality is ≤ 1.0 *T. saginata* egg/L as part of the supply agreement.

(ii) High risk if these LRVs or equivalent approved by the CVO or relevant authority are not achieved.

The cattle industry risks are in part similar to the Australian Guidelines for Water Recycling (AGWR), which indicates that a 4.0 LRV or equivalent is required to control the risks of *T. saginata* eggs in recycled water and possible exposure to cattle (NRMMC et al., 2006). However, the cattle industry also recognises that since the publication of the AGWR in 2006, a significant body of peer-reviewed research has indicated that:

- Helminth eggs of concern in sewage in southern Australia are typically ≤ 1.0 HE/L and *T. saginata* eggs have not been detected in the last decade (i.e. < 0.5 to 1.0 HE/L, depending on the Limit of Reporting) (Stevens et al., 2021a).
- A recent Quantitative Microbial Risk Assessment has identified that an LRV of 3.0 would not change the current risks identified in Australia unless there is an unmonitored disease outbreak in a sewer catchment (Stevens et al., 2017).
- Reduced exposure LRV (LRV_{RE}) can be used to reduce the risk of exposure of cattle to helminth eggs that might be in recycled water (Stevens et al., 2021a). Where the Total LRV = LRV + LRV_{RE}

Given the above, the AGWR and state/territory guidance should acknowledge these advances in risk management for *T. saginata* in recycled water production.

The ISC fact sheet supports the Livestock Production Assurance and National Livestock Identification System (NLIS) amendments for the new risk management framework for recycled water use for cattle production (ISC, 2023)[1]. This framework also supports recent updates to the Australian Standard for the Hygienic Production and Transportation of Meat and Meat Products for Human Consumption (AS4696:2023) (Standards Australia, 2023). The Australian industry support these changes, with SAFEMEAT[2] approval representing endorsement by the jurisdictions and industry.

LRVs from wastewater treatment

The facultative waste stabilisation ponds used in wastewater treatment plants (referred to as lagoons here after, are usually 1.2 to 2.4 m in depth and are not mechanically mixed or aerated) have been assessed extensively internationally for the LRV of helminth eggs. The LRV achieved by facultative lagoon systems has been well documented and accepted, based on the hydraulic retention time of well-designed, managed and maintained lagoons (NRMMC et al., 2006; Stevens et al., 2017, 2021b) (Table 1). There is now sufficient evidence that various forms of primary sedimentation and clarification with ASP can achieve a minimum LRV of 0.78 when well-operated (Table 1, Figure 2).

Treatment processes other than ASP and lagoons can also provide LRVs (Table 1). However, removal rates vary considerably based on the related parameters for a specific treatment process, and the data is often limited. Data limitations are influenced by the limited use of highly engineered solutions (e.g., Ultraviolet and Ozone) for helminth egg removal due to the cost of operation and the low helminth egg concentrations where these types of treatments have been used.

1 https://www.integritysystems.com.au/siteassets/risk-management-of-c.-bovis-fact-sheet_2023_13-12-23.pdf
2 https://www.integritysystems.com.au/about/news--events/news/2023/new-risk-management-framework-for-recycled-water-use/
https://www.safemeat.com.au/

Table 1: Log Reduction Values (LRV) of various pathogens for processes in the wastewater treatment plant (WWTP)

WWTP treatment process component	Helminths egg LRV		Helminth species identified in the literature	Reference
	AGWR range	Literature mean (range)		
Primary treatment (Primary Sedimentation)	0–2.0	1.74 (0.78, 2.82) n=21	*Ascaris* sp., *Trichuris* sp., *Taenia* sp., *Toxocara* sp. *Tristrongyloides* sp. and *Strongyloides* sp.	Figure 2
Secondary treatment (Activated Sludge Plant (ASP) with Clarification)	0–2.0			
Filtration (Sand/multimedia)	--	1.1 (0.7,2.4)	Not defined	(Mara and Horan, 2003)
Filtration (Disc/cloth filters)	--	2.0	*Trichuris suis*	(Quinzanos et al., 2008)
Facultative maturation ponds (Lagoons)	--	0.2 to >4.0	--	(Stevens et al., 2017, 2021b)
Chlorination	0–1.0	No data identified	no suitable data was identified	--
Ozonation	N/A	1.22 (0.26, 1.48) n=5 Dose = 180 to 300 mg/L.min	*Ascaris suum, Strongyloides stercoralis, Diphyllobothrium latum, Ascaris lumbricoides, Hymenolepis nana, Toxocara canis* and helminth eggs	(Rojas-Valencia and Velásquez, 2002; Ried and Mielcke, 2006; Campos-Reales-Pineda et al., 2008; Zamudio-Pérez et al., 2014)
UV light	N/A	1.0 (0.12, 1.10), n=5 Dose = 136 to 250 J/m²)	*Opisthorchis felineus* and *A. lumbricoides*	(de Lemos Chernicharo et al., 2003; Keller et al., 2004; Lipatov et al., 2017)
Dual media filtration with coagulation	2.0–3.0	Not considered		
Membrane filtration	>6.0			
Reverse osmosis	>6.0			
Lagoon storage	1.5–>3.0			
Wetlands, surface flow	0–2.0			

AGWR = Australian Guidelines for Water Recycling (NRMMC et al., 2006). Sources quoted by AGWR: WHO (1989), Rose et al. (1996, 2001), NRC (1998), Bitton (1999), USEPA (1999, 2003, 2004), Mara and Horan (2003). N/A - not available; UV= ultraviolet. Reductions depend on specific process features, including detention times, pore size, filter depths, and disinfectant. For ozone and UV, the LRV can be based on the inactivation or destruction of the helminth egg (HE). *n* = number of samples. -- = blank.

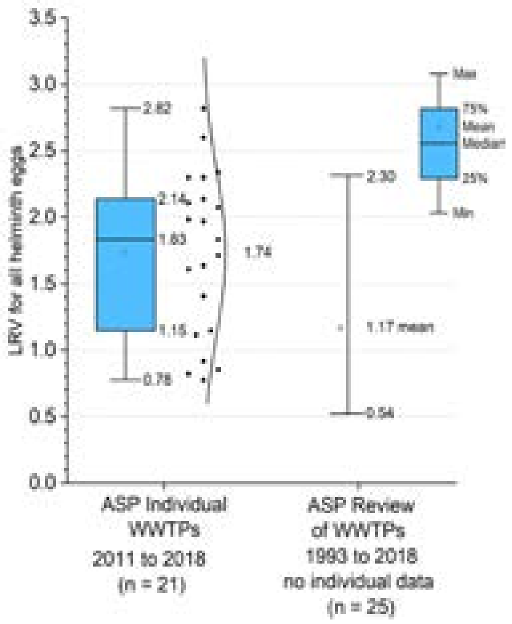

Figure 2: Range in Log Reduction Values (LRV) of helminth eggs measured from raw sewage to post the Activated Sludge Plant (ASP) for recent data extracted from the literature and considered not to be compromised (blue box) and the range indicated from a review in 2018 (Zacharia et al., 2018) (right bar). The ASPs for individual wastewater treatment plants (WWTP) were confirmed as primary settling and/or conventional activated sludge plants. They were considered the predominant treatment for the removal of helminth eggs.

Equivalent LRVs

Equivalent LRVs relate to LRVs attributed to cattle's reduced exposure (LRV_{RE}) to helminth eggs that are potentially in recycled water by factors other than treatment by the WWTP. In the above context, "or equivalent" could be an LRV_{RE} of 0.5 due to a large WWTP and an LRV_{RE} of 0.5 for ongoing monitoring of the helminth eggs in the sewage entering the WWTP (Table 2). Recent research has assessed the potential LRV_{RE} and the risk to cattle from *T. saginata* eggs found in sewage and quantified several reductions in exposure scenarios (Table 2). All these scenarios could apply to the "or equivalent" term and use of recycled water. Those that are easily achieved are:

1. Large WWTP with sewage monitoring for outbreak provides 1.0 LRV_{RE} (No. 1 and 5, Table 2). Monitoring provides a CCP.
2. Cattle should be provided with a source of drinking water that is not recycled water, providing an LRV_{RE} of 1.0 (No. 2, Table 2). Alternate sources of cattle drinking water should be considered good practice, as it can also minimise exposure to other potential hazards in recycled water.

If a Total LRV of 4.0 is required, then the LRV_{RE} of 2.0 would only require another 2.0 LRV from the treatment process (i.e. Total LRV = LRV_{RE} + LRV). The use of several treatment LRVs and LRV_{RE} provides a multibarrier approach with the possibility of CCPs ensuring the recycled water supply meets these criteria. The Quality Assurance (QA) points identified in Figure 1 would typically provide logical points for CCPs.

Implications for recycled water and cattle producer

Implications for recycled water production

Wastewater treatment plants have environmental licences with state or territory governments to treat sewage and return recycled water to the environment. The AGWR (2006) set the treatment standards and options available for recycled water. However, due to the limited data available at the time of publication, the AGWR risk assessment approach for using recycled water for cattle production relied on a historical reflection.

If a WWTP's environmental licence allows it to release water for livestock grazing, the state or territory environmental authority is typically informed and may seek further advice from the related agriculture departments or equivalent. The WWTPs should enter into agreements to supply recycled water to a cattle producer and provide the producer with information on the treatment level achieved for CB. Specifically, whether the recycled water supplied to the producer has been treated to achieve the LRV indicated above and defined as either low or high risk for CB.

The treatment requirements are now defined so that recycled water producers know what measures to put in place to mitigate the risk of CB in cattle. If recycled water is defined as high risk and exposed to cattle directly or pasture grown with it, then the NLIS system will identify these cattle as requiring additional requirements for PMI. Ideally, low risk status is preferred as it minimises complications from a property or animal being identified with a CB Status.

Table 2: Log Reduction Values for Reduction in Exposure (LRV_{RE}) proposed for different scenarios

No.	Exposure scenario	LRV_{RE} [A]
1	Larger wastewater treatment plants (WWTP) (≥ 5 ML/d)	0.5
2	Limited ingestion of recycled water by cattle from livestock drinking water	1.0
3	One year of exposure to plant biomass irrigated with recycled water	0.5
4	Fodder cut and removed for feeding off-site	2.0
5	Sewage monitoring for outbreaks	0.5 [B]

[A] The LRV_{RE} are added to the LRV achieved by the wastewater treatment plant to provide a total LRV (Stevens et al., 2021a).

[B] Monthly sampling and monitoring of the data, to cease supply if high concentration is detected in sewage, should minimise expose to cattle if an outbreak is detected. This frequency should be considered in the context of the specific WWTP.

The benefits of this system are that the producer and user of recycled water can now use a risk-based approach to managing *T. saginata* eggs in sewage and the risk associated with CB in cattle. Such an approach allows consideration of 3.0 LRV with an alternative water supply for cattle to drink, or other appropriate conditions if approved by CVO or other equivalent government departments.

When implemented with the appropriate controls and monitoring, the clarity achieved by this risk-based approach should allow lagoon systems struggling to achieve an LRV of 4.0 to supply low risk recycled water with 3.0 LRV from the WWTP and other appropriate LRVs from reduction in exposure (LRV_{RE}). For example, a shift from a 4.0 LRV from the WWTP to 3.0 LRV represents a decrease in hydraulic retention time (HRT) for a lagoon of 4.4 to 4.5 days (a decrease of 22%, based on 80 and 95 % of lagoons (Stevens et al., 2021b)). This decrease in HRT requirement should allow longer use of infrastructure while maintaining low risk status for recycled water supplied to cattle.

Auditing of the recycled water treatment and supply should be integrated with the auditing required by the user, cattle production system and the related food safety requirements.

As many WWTPs also have additional treatment processes to the lagoon, recognition of the removal via these processes may also be appropriate. For example, in many endemic countries where the helminth egg concentration is sufficient to measure, ASPs have achieved a mean LRV of 1.74 (0.78, 2.82) (Table 1). A well-operated ASP with CCPs should achieve a minimum LRV of 0.78 (Figure 2). If an LRV of 3.0 is required, as the site achieves an LRV_{RE} of 1.0, a WWTPs with an ASP and a facultative lagoons system (designed to achieve HRTs and settling of particles (Stevens et al., 2021b)) would only require an LRV of 2.22 for the lagoon system as the ASP provides an LRV of 0.78 (i.e., 0.78 + 2.22 = 3.0). This ASP + Lagoon system would then achieve a 35% to 39% decrease in the HRT required for the lagoon system, based on 80 and 95 % of lagoons (Stevens et al., 2021b).

Implications for cattle husbandry

The potential impacts for cattle husbandry from recycled water are described in full in the ISC fact sheet and are summarised below (ISC, 2023).

Producers who use recycled water for irrigation or cattle drinking water must demonstrate that recycled water does not pose a risk to food safety (i.e., the recycled water is **low risk**). Low risk recycled water should be demonstrated through conformity to Element 1 of Livestock Production Assurance, i.e., the property risk assessment (ISC, 2023).

Producers being supplied with recycled water from a WWTP need to:

- Include recycled water use in their property risk assessment.
- Indicate on their farm map where recycled water has been applied.
- Obtain in writing from the WWTP the treatment level of the recycled water (agreement or contract).
- Demonstrate through the agreement that the recycled water is low risk and has been treated to achieve a:
  - LRV of 4.0 in *T. saginata egg* concentration or equivalent; or
  - LRV of 3.0, only if the producer supplies other fresh drinking water to cattle. The recycled water supplier must confirm that the sewage quality is ≤ 1.0 *T. saginata* egg/L as part of the supply agreement.

These ISC requirements should integrate well with the associated Health and Environmental Management Plans, or the like, that are required to manage the associated risks when supplying and using recycled water (NRMMC et al., 2006; EPAV, 2021a, 2021b).

If exposed to inadequately treated recycled water (**High risk** recycled water), cattle need to be identified, traceable and declared as exposed to CB on outgoing National Vendors Declarations.

The ISC (a wholly owned subsidiary of Meat & Livestock Australia that provides a system of food safety measures, quality assurance and traceability from paddock to plate, guaranteeing the integrity of Australia's red meat industry) will send Livestock Production Assurance auditors to audit producers to verify the treatment level of recycled water in use where CB is detected in cattle at processing. State/territory officials will manage detections for all non-Livestock Production Assurance accredited producers. Producers verified as using inadequately recycled water will now have a:

- CB PIC-based status (**CBP**) on the National Vendors Declarations form status applied to their PIC in the NLIS Database, and
- CB Animal identification device status (**CBA**) applied to all cattle identification devices on their PIC.

The CBA device status will remain on the device for the animal's lifetime to instruct the processor on the correct inspection procedure to follow at processing. The CBP status can only be removed from a PIC once a Livestock Production Assurance auditor verifies it has been two years since inadequately treated recycled water use has ceased on the PIC or a state/territory official removes the status through a risk assessment.

The ISC indicate that in certain circumstances cattle may also require a CB Warning status (CBW defined as an Early Warning - EW(CB) by NLIS) or have the CBA status removed (ISC, 2023). There are also re-tagging requirements for cattle that lose their tags. Several requirements for the sale yards, feedlots and processors are also associated with the CBW, CBP and CBA statuses are also defined (ISC, 2023).

CONCLUSIONS

The updated CB risk management strategy for the beef industry integrates well into recycled water production by the water industry. For safe pasture and fodder production for cattle, the requirements for LRVs are defined to ensure the recycled water is low risk for helminth egg removal. The strategy also recognises that equivalent, alternative risk-based LRV and LRV_{RE} can be defined but should be accepted by the EPA, CVO or relevant authority.

The approach described allows for adopting rational risk-based LRVs for recycled water production based on site-specific sewage catchments and LRV_{RE} or various exposure scenarios. Such a risk-based approach allows more efficient classification and use of the LRV for various water treatment processes, rationalising the cost of water treatment to the water industry while maintaining a low risk status for the recycled water produced for pasture and fodder production for cattle.

The exposure of high risk recycled water to cattle does not prevent their sale. However, it complicates the NLIS status of these animals, the properties where they are kept, and the processing of the animal. There are no impacts to other cattle with no CB Status when comingled with cattle with a CB Status, as CB is not spread from animal to animal as cattle are the intermediate host, and the lifecycle requires the definitive host (Humans) to be transmitted to cattle (Figure 1).

The production and supply of recycled water adopted a hazard analysis and critical control point (HACCP) from the food industry (Formalised in 2006 (NRMMC et al., 2006)). The CB risk management framework for the recycled water industry integrates the HACCP approach with cattle production. It provides further opportunities to value-add recycled water and deliver a sustainable outcome as water security wanes.

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AMPC is thanked for funding a suite of projects that extracted specific information from the recycled water industry, animal production sector, processing sector, and the jurisdictions for translation into a cross-sector risk management framework for CB. The AMPC Steering Committee members for the project are gratefully acknowledged for contributing their industry and regulatory knowledge and experience.

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