30 April 2020

Dr David Cunliffe
Chair
enHealth Water Quality Expert Reference Panel
david.cunliffe@sa.gov.au

Dear Dr Cunliffe

RE: SUBMISSION TO THE REVIEW OF THE AUSTRALIAN GUIDELINES FOR WATER RECYCLING

Thank you for the opportunity to provide a submission to the Review of the Australian Guidelines for Water Recycling (AGWR). We consulted with our water utility members around Australia and their feedback is summarised in this submission.

In general, we are supportive of the proposed changes. The Explanatory Paper on the proposed revisions is clear in the drivers for change, and in describing the detail of the proposed changes. In summary, the new version will be improved by:

- Incorporation of current published science since the first version of the AGWR was released in 2006
- Alignment with the Australian Drinking Water Guidelines
- Alignment with WHO publications, particularly WHO's publication *Potable Reuse: Guidance for Production of Safe Drinking-water*
- Simplification of the text in many places.

There are two areas where we recommend additional work and further consideration:

- Assessment and management of helminths risks
- Clarify log removal values.

Beyond this, we recommend minor changes to clarify and improve the AGWR, as per Attachment 1, and identified minor typographical errors, as per Attachment 2.

Assessment and management of helminth risks
The AGWR should be updated to adopt a risk-based approach to the management of helminth eggs in sewage that is used to produce recycled water. In our view, the draft AGWR does not utilise a risk-based approach that considers the actual risks experienced across Australia.

The draft revision adopts guidelines and management practices based on exposure scenarios in countries where helminth infections are endemic. In Australia, where helminth infections are generally not endemic, this approach leads to excessive treatment requirements and over management of the associate risk. The AGWR should adopt a risk-based approach to the management of helminth eggs in the production of recycled water that is consistent with the approach used for the management of the health risks associated with other pathogens in the guidelines.

Our members have participated in work undertaken by Dr Daryl Stevens and Dr Aravind Surapaneni to prepare the accompanying document - *Proposed improvements for helminth egg management in the AGWR revisions: 2020* (Attachment 3). We recommend that consideration be given to adopting the proposed improvements into the guidelines.

Clarify log removal values

The draft AGWR increases the virus, protozoa and bacteria LRV targets and requirements. We are aware that in at least one example, the increase in the protozoa LRV from 3.5 to 4.5 for municipal uses will result in a substantial increase in treatment requirements, where existing MBR-Chlorine processes, which are common for this type of end use, are able to deliver an LRV of 4.0. As a result of the proposed change, MBR-Chlorine schemes that currently provide water for unrestricted irrigation will need to find an additional 0.5 log reduction. In practice, that will probably mean moving to an additional UV barrier, which does not seem to be justified, in the absence of clear evidence that an LRV of 4.0 creates an unacceptable risk to end-users. We provide further detail of this example, and options to improve the AGWR, in Attachment 1.

Additionally, in the draft revision of the AGWR the log removal values are inconsistent between different sections and tables. Further, the increase in protozoa and bacteria LRV target/requirement compared to AGWR 2006 are inconsistent, as in some instances the LRV has increased by 0.5, where at other times it has increased by 1 LRV. These inconsistencies need further review, explanation and justification with respect to the management of end user risk in the AGWR. Again, we provide further details on this matter in Attachment 1.

For your information, the Water Services Association of Australia (WSAA) is the peak industry body representing the urban water industry in Australia. Our members include all the water utilities supplying water and wastewater services to over 24 million customers.

We acknowledge our members, Coliban Water, Hunter Water, Icon Water, Seqwater, SA Water, South East Water, Sydney Water, TasWater and Water Corporation for their contributions to this submission.

I would be happy to discuss our submission further on 0417 211 319 and adam.lovell@wsaa.asn.au

Kind regards

Adam Lovell
Executive Director
Water Services Association of Australia

Attachment 1: Improvements to the draft AGWR

<table>
<tr><th>Section</th><th>Page</th><th>Text</th><th>Comments</th></tr>
<tr><td>General</td><td></td><td></td><td>Adopt recommendations in Proposed improvements for helminth egg management in the AGWR revisions: 2020 provided in Attachment 3.</td></tr>
<tr><td>General</td><td></td><td></td><td>We recommend and support the revision of AGWR Phase 2 guidelines as soon as possible to bring them in line with the amendments in the AGWR Phase 1.</td></tr>
<tr><td>1.2</td><td></td><td>• Stormwater recycling for residential uses, urban irrigation, agricultural and industrial purposes, as well as fire fighting (NRMMC, EPHC & NHMRC 2009b).
• Managed aquifer recharge, as a component of recycled water schemes (NRMMC, EPHC & NHMRC 2009a).</td><td>What is the status of the review of these other referenced documents?</td></tr>
<tr><td>2.2.1</td><td>19-20</td><td></td><td>Dot points under “Factors to consider could include:” could be grouped into risk factors – eg. some are operational and some are environmental. And environmental could be ordered in sequence of factors potentially impacted.</td></tr>
<tr><td>Box 2.3</td><td>20-21</td><td></td><td>Examples discuss internal cross connection checks, but do not provide an example on how to check or confirm the recycled network for the removal of cross connections between potable water network pre going live with the system. This guidance would provide a useful reference point for utilities wanting to commence recycled water supply to customers.</td></tr>
<tr><td rowspan="2">Box 2.6</td><td rowspan="2">33</td><td>Protection and maintenance</td><td>Protection and maintenance section could include:
- Backflow prevention and cross connection control in distribution systems.
- Regular internal cross connection checks
- Installation of additional monitoring e.g., conductivity meters and live free available chlorine instrumentation to determine system anomalies across the dual reticulation system.</td></tr>
<tr><td>Restrictions on distribution system</td><td>Restrictions on distribution systems and application site section could mention additional measures:
- Removing water cartage access in the dual reticulation network
- Clamping or locking of recycled water hydrants</td></tr>
</table>

Section	Page	Text	Comments
			- Not labelling recycled water hydrants on power poles so that they are not identifiable to public/water cartage companies, particularly if firefighting and dust suppression are not intended end uses.
		Users of recycled water	Could include best practice management for operators e.g. during recycled water quality flushing, during recycled water main repairs, and temporary cross connections for continuity of supply.
2.3.2	36	Similarly, in setting a minimum lagoon detention time to achieve pathogen or nutrient reduction, a critical limit might be 50 days and a target criterion might be 55 days.	Consider clarifying that the lagoon detention time of 50 days is for primary treatment source, as secondary treatment sources have different detention times, as specified in Table 3.9.
Table 3.1	75	Microorganisms of concern to humans in sewage	Confirm the list of viruses that are being cited are a risk in wastewater, and if the “illness” identified is accurate. For example, coronavirus is listed as causing Gastroenteritis.
Table 3.3	84	Ultraviolet light disinfection (UV)	The basis of the validation for UV disinfection dose indicates two different validated doses can achieve the validated LRV of 4.0. However, if the lower dose is adopted, the virus validated LRV of 4.0 is not achieved. Should this be a range, as similar to RO?
		Row: ‘Micro or ultrafiltration (MF/UF)	Unclear why 0 virus LRV is claimable for MF/UF. The column for viruses has a ‘d’ superscript, but there is no ‘d’ in the table legend explaining this superscript.
		Secondary treatment	It would be helpful to define, or separate out, types of secondary treatment. This would be the most common wastewater treatment barrier and there is a wide range of possibilities in this section. What is it that defines one as better than the other with regard to LRVs. Lagoons versus Oxidation Ditch versus SBR versus MLE Activated Sludge Plant.
Table 3.3 Table 3.8		Differences between LRVs in Table 3.3 and Table 3.8	The LRV credit range in Table 3.8 does not line up with the default or minimum LRVs in Table 3.3. Instead, it appears to show what is possible to achieve, rather than what is likely to be credited without validation. For example, in Table 3.3: Secondary Treatment states that the default LRVs are 0.5 -1 for viruses, 0.5 for protozoa and 0.5-1 for bacteria. There is nothing given for chlorination without Ct. In Table 3.8, when considering Municipal Use, with restricted access and application, the third column - Secondary Treatment with disinfection (chlorine or UV) gives 2.5-3.0 LRV for viruses. Even if you were achieving 1 log for viruses at secondary treatment, the remaining 1.5 log must be achieved via disinfection. If the system is a lagoon, followed by chlorination, achieving 1.5 log via disinfection will be unachievable in many cases.
Table 3.7 Table 3.8		Differences between LRVs in Table 3.7 and Table 3.8.	There needs to be some more commentary to explain why there are differences between the LRV values in Table 3.7 and 3.8. Also, there should be further explanation as to which LRV are to be used for design or review of a scheme. For example, if a specific use/s, as per the Table 3.7, are

Section	Page	Text	Comments
			relevant to the scheme, should Table 3.7 be used, or should the more generic uses, as in Table 3.8, be used. We also note the increase in Protozoa and Bacteria LRV target/requirement compared to AGWR 2006 is inconsistent, sometimes increased by 0.5 LRV and other times 1.0 LRV. This needs further explanation.
Table 3.8	98-103	Chlorination residuals v Ct values	The maintenance of chlorine residuals has been removed and replaced with Ct values. - In many cases, especially for lagoon sites, maintaining a free chlorine Ct, and controlling it, will not be achievable. - Lagoon effluent can contain high concentrations of ammonia and algae cells, both of which have a significant chlorine demand. In many cases, trim dosing with total chlorine analysers is required, but free chlorine is not measured. Is there any scope to consider total chlorine Ct values?
Table 3.8	98	Row: Municipal use – open spaces, sports grounds, golf courses, dust suppression, etc or unrestricted access and application	The draft Guidelines increase in protozoa log reduction requirement from 3.5 to 4.5 for municipal uses. This will result in a step change in treatment needs for some schemes, by going over 4.0 LRV which is the LZRV limit for the membrane filtration process. Hunter Water, and many other utilities, have used, or do use, a MBR-Chlorine process train for unrestricted irrigation schemes. The MBR achieves the 4.0 log protozoan pathogen reduction. In some cases, the membrane filtration process takes effluent from an activated sludge process after a settling, clarification and decanting step. Such processes can achieve a nominal 0.5 log reduction for the secondary treatment which, when combined with the routinely achievable 4.0 log reduction from the membrane filtration process, provides for a 4.5 log reduction. For such processes, no step change arises, other than possibly making the existing secondary treatment process a CCP, and/or tightening up the membrane integrity test limit from 3.5 log to 4.0 log. However, MBR processes take mixed liquor directly onto the membranes and don't have a separate clarification process step. As such, they are limited to a 4.0 log reduction for the combined secondary and tertiary membrane treatment process. The result is that for MBR-chlorine schemes that currently provide water for unrestricted irrigation there will be a need to find an additional 0.5 log reduction. In practice, that will probably mean moving to an additional UV barrier. Given that the shortfall would only be 0.5 log, and that a step-change would be required to achieve it, there may be options that could be identified within the guidelines that would avoid creating a step-change in the treatment requirements for this common MBR-chlorine process train - one that is used for many unrestricted irrigation schemes; for example: 1. Consider that the biological processes taking place in the activated sludge secondary treatment component of the MBR can achieve a nominal 0.5 log reduction, even without a dedicated decant step, taking the total log reduction to up to 4.5 log (4 log for the validated reduction by the

Section	Page	Text	Comments
			membrane, plus 0.5 log for the processes occurring in the activated sludge process). This could, for instance, consider biodegradation occurring in the biological process, and note that the turbidity drop across a MBR process is often very high. Such an alternative would need to be backed up by additional testing, such as clostridial spores, as part of verification monitoring. 2. Consider rounding down the LRV to 4.0, rather than up to 4.5. We note the differences in LRV between Table 3.7 and Table 3.8. 3. Review exposure assumptions used to determine the LRV. For schemes that have relatively infrequent users, consider reviewing specific end uses and note that some exposures are more likely to be fortnightly, or even less (leading to a 4.0 log reduction requirement).
			The "LRV required in total" listed bacteria log (• 4.5 bacteria) does not correspond with "Treatment controls and associated LRV" listed bacteria log (• 5.0 bacteria).
		Column: Treatment controls and associated LRV	The "Treatment controls and associated LRV" column is confusing; it would be good to reference the Table 3.3 LRV for each process step, instead of listing 'example LRVs'.
	102	Row: Commercial food crops Column: 4th, Exposure control and associated LRV	Missing an LRV for Consumers, Crops with no ground contact and heavily processed (e.g. grapes for wine production, cereals).
Table 3.9	106-107	Livestock watering	It is not clear why the recycled water described under the last two categories ‘Pasture or fodder crop irrigation (including hay, silage and commercial fodder production). Limited withholding period (not to be drunk by livestock)’, and ‘Pasture or fodder crop irrigation (including hay, silage and commercial fodder production). With withholding period (not to be drunk by livestock)’ are unsuitable for livestock watering. They have helminth control and the same water quality indicator levels as livestock water, and the former has disinfection. It would be helpful to clarify why these two are not suitable for livestock watering.
		Column: Water quality objective	Add an annotation to ”Water quality objective” column to specify the concentration limits, i.e. to be same as included in Table 3.8 [c Water quality objectives represent medians for numbers of *E. coli* and means for other parameters.]
		Column: Indicative treatment processes “…to achieve the pathogen reduction required) and disinfection.”	After “and disinfection” consider adding " ......or equivalent process to achieve the pathogen reduction required". It is suggested that UV or chlorination is not required if required the LRV is achieved with a filtration step. As specified in Table 3.3 (LRV achieved), and on pg 145, "Membrane filtration may be used as an alternative to conventional media-based processes, because it provides a direct physical barrier and can remove more microorganisms".
5.2.3	114	Validation monitoring, for example challenge testing, should be	We raise the following clarifying questions and concerns:

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		performed, or at least overseen in detail, by an independent and appropriately qualified professional or group of professionals. The work would need to be overseen by someone independent of any organisation with a stake in the system and of the laboratory that does any necessary microbial validation testing. Such oversight provides independent assurance that both the system being validated, and the sampling strategies and laboratory techniques being applied are sound".	- Is the text in the AGWR referring to validations performed for specific technology, unique to the manufacturer/model e.g. a specific UV Disinfection unit or a specific UF membrane system, or is it for referring to any validation testing that could be performed on an installed process, such as Activated Sludge Process or DAFF? There are two different scenarios which may require different rules e.g. A manufacturer seeking to gain LRV credits and regulator endorsement on their technology versus a utility testing their installed process e.g. an ASP, DAFF, Lagoon etc, where there is no commercial gain. - There are very few people/consultants who have the expertise to do this work, or 'oversee' the process. - Third party oversight adds considerable expense to validation - The oversight does not provide "independent assurance" of the soundness of the validation. Any validation testing should be done by following a recognised guideline (like WaterVal wants to become), or be designed in agreement with the relevant health regulator. - Utilities should be encouraged to perform their own validations. For example, in SA Water's experience, SA Water has learnt a great deal about its systems through performing validations, which has helped them to "know their systems", which is what risk-based guidelines are designed to do. SA Water has developed validation testing protocols by collaborating internally with our research, operations and AWQC teams, and by seeking endorsement on the protocol with the regulator.
5.3.1	117-118	Microbial validation monitoring	It is unclear where the recommendation for twenty samples is derived. The preceding text suggests inlet and outlet samplings at ideally five locations.
Table 5.3	120		Consider including dose as the operational management parameter, since the LRV table relates to validated dose.
Appx 3 Table A3.6	150	Table A3.6	We appreciate that Table A3.6 is provided to give a range of potential CCPs and operational criteria for a selection of treatment processes, but the CCPs listed in Table A3.6 are all for rather conventional treatment processes. While we appreciate that it is likely to be a fair bit of additional work, it would be advantageous if Table A3.6 listed potential CCPs and operational criteria for all the processes listed in Table 5.3, in order to provide a level of consistency across the guideline document, and, perhaps, promote a level of consistency across the country with respect to "recommended" CCPs and operational criteria for all the processes listed in Table 5.3.
Appx 3, A3.2.3	146-147	Sub-heading Prolonged detention in lagoons or wetlands Sub-heading Chlorination	Suggest that the following text is moved from page 147, where it appears in the 'Chlorination' paragraph, to page 146, to replace the first paragraph of the section on 'Prolonged detention in lagoons and wetlands': 'Detention of treated effluent or stormwater in lagoons and wetlands can reduce substantially the numbers of pathogenic bacteria, protozoa and helminths. Virus numbers will also be reduced, but not as quickly. *Giardia* is rapidly removed by lagoon detention, and helminth eggs can be completely removed within 25 days. Detention can also reduce turbidity.'

Section	Page	Text	Comments
	147	Under sub-heading Disinfection However, there is some evidence that UV light irradiation might be effective in inactivating Cryptosporidium, and combinations of disinfectants can improve inactivation.	We would argue that it is now widely accepted that UV is a standard method for the inactivation of *Cryptosporidium,* so this text can be strengthened.
General (S3.4 from explanatory paper)	4	Table 5.5 is considered to be too detailed and Table 5.6 is too prescriptive	While we acknowledge the reasoning for the removal of these tables, these tables were useful and we would like to see a little more on the frequency of verification monitoring included in the AGWR.
General (S4.2 from explanatory paper)	4	The main challenge is the 0.5 log increase in the performance targets for protozoa. For high exposure schemes using high levels of treatment this could require small enhancements of existing treatment processes.	**Change in protozoan LRV target, overarching** The potential challenge of an increase of 0.5 log in performance targets for protozoa is noted and it is agreed that for high exposure schemes the impact is low (as the LRV is high so the percentage change is quite low).
General (S5 from explanatory paper)	4-5	Depending on the outcomes of consultation on these revisions there could be implications for the calculation of performance targets in the Phase 2 modules for drinking water augmentation and stormwater harvesting and reuse.	Change in protozoan LRV target, Stormwater Reuse Given the impending review of the AGWR Phase 2 Stormwater Harvesting and Reuse guidelines, some additional comment in the commentary on lower exposure schemes using non-treatment measures to reduce exposure is probably appropriate. It is suggested that the table on LRV's for stormwater reuse is refined to link explicitly to Table 3.6 in the existing AGWR Phase 2 Stormwater Harvesting and Reuse guidelines and make it clear whether: a) The LRV's are the same for unrestricted and restricted use and b) What the implications are (if any) for both treatment and on site preventative measures The way I read this LRV's assigned for on-site preventative measures will meet the revised LRV's, and the LRV's are the same for restricted and unrestricted use.
General (S5 from explanatory paper)	4-5	Depending on the outcomes of consultation on these revisions there could be implications for the calculation of performance targets in the Phase 2 modules for	**Trigger for Review of AGWR Phase 2 for Augmentation of Drinking Water Supplies** It seems logical that this would also trigger as revision of the AGWR Phase 2 for Augmentation of Drinking Water Supplies. This would be supported by Water Corporation and it is noted we have recently completed some excellent work with US experts on Probabilistic Quantitative Microbiological Risk Assessment (PQMRA) which could be used to significantly enhance, for instance, Section 4.4.2 and Section 5 in the guidelines, bearing in mind that when the guidelines

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		drinking water augmentation and stormwater harvesting and reuse.	were written there were NO operating schemes in Australia, and the above work informs on how to identify areas for improvement in monitoring and control of existing systems.

Attachment 2: Detailed typographical comments on the AGWR

Section	Page	Text	Comments
Box 2.3	21	Information about the nature and concentration of chemicals in recycled water was sometimes inadequate**, and**.	Third line on page 21. Sentence ends incompletely with ‘and’
Figure 2.1	23	Biota	Figure 2.1 box in green “Biota” includes fauna and flora, however “Plants” is another box within the larger green box.
Table 2.2	28	Column: Classification	Consider moving bracketed measurement notes below ‘Conventional’ and ‘Emerging’ to the footnotes to the table.
2.2.4	28	Immediately above Table 2.2: Further information on sources of hazards and hazardous events are provided **in Appendix 3.**	Consider adding the specific section or table references in Appendix 3 to make the further information easier to find.
2.9.1	57	Reference to WaterSecure 2017a-d	With respect to Water Secure’s WaterVal protocols, five were finalised and published, but only four are listed. The reverse osmosis and nanofiltration protocol is published and should be listed. Additionally, Water Secure no longer exists, but the protocols sit on the Water Research Australia website, and the reference list should include a hyperlink to them to assist readers to find them (https://www.waterra.com.au/research/waterval/)
3.1	68	Acceptable chemical risk is traditionally defined through the setting of guideline values as **described the** Phase 2 guidelines (NRMMC et al 2008).	Change to add word ‘in’: Acceptable chemical risk is traditionally defined through the setting of guideline values as **described in the** Phase 2 guidelines (NRMMC et al 2008).
		…exposures to be controlled, in **order reduce**	Change to: …exposures to be controlled, in **order to reduce**
Box 3.1	71	…the severity of the disease on a scale from 0 (perfect health) to 1 **(dead).**	Change ‘dead’ to ‘death’, since ‘death’ is used in every other instance in Box 3.1: …the severity of the disease on a scale from 0 (perfect health) to 1 **(death).**
		Using an Australian example, infection with **Norovirus causes2**:	Change to: Using an Australian example, infection with **norovirus causes**:

Section	Page	Text	Comments
			Unless the '2' should be a superscript and reference to a footnote somewhere.
3.1.3	72-73		In five instances in section 3.1.3, the Health-Based Target (HBT) is just referred to 1µDALY, whereas it probably should be referred to in all cases as **1µDALY per person per year (or 1µDALY pppy).**
3.2.1	76	the significance of rotavirus will be reduced over time by the introduction of a vaccine **that will change** the incidence and severity of disease outcomes from this pathogen (Gibney et al 2014).	Change to: the significance of rotavirus will be reduced over time by the introduction of a vaccine **has changed** the incidence and severity of disease outcomes from this pathogen (Gibney et al 2014).
3.2.1	76		References incorrect or missing: WHO 2016 – missing from reference list on pages 153-161. Gibney et al – reference in text appears to be wrong (listed as Gibney et al 2010, rather than Gibney et al 2014)
		there is limited information on helminth occurrence in water and limited human dose–response **model** (Navarro et al., 2009; Navarro and Jiménez, 2011).	Change to: there is limited information on helminth occurrence in water and limited human dose–response **models** (Navarro et al., 2009; Navarro and Jiménez, 2011).
	77	Variability in pathogen concentrations is likely to be lower at major **metropolitan treatment plants**	Change to: Variability in pathogen concentrations is likely to be lower at major **metropolitan wastewater treatment plants (WWTP)**
3.2.3	81	For instance, the probability of infection **per ingested** is higher	Should this be "**per ingested pathogen**"?
3.3	82	Reference to AS/NZS ISO 31000:2009	Could be updated to AS/NZS ISO 31000:2018
3.3.2	83	Over time more and more **processes have** their pathogen LRV validated based on evidence	Change to: Over time more and more **processes will have** their pathogen LRV validated based on evidence
Table 3.3	84	Helminths LRV	Helminths LRV no longer available in guidelines.

Section	Page	Text	Comments
			Helminths LRV removed from this table, still referred to in notes.
		Row: Chlorine	The basis for validation describes the following "A concentration x time (Ct) value associated with 4 log virus (and bacteria) inactivation is => **15mg/L** (ie **0.5mgL** for 30 min)" There are two errors **0.5 mg/L** not 0.5 mgL and the Ct unit is mg.min/L, so we think that that may be the figure of 15 from the equation in the table (**15mg.min/L**)?
3.3.3	85	Although preventive, measures such as…	The following three sentences don't seem to logically follow one another and appear to internally contradict themselves, and, as such, should probably be reviewed: Although preventive, measures such as signage, labelling and communication, are important for reducing risks, no numerical hazard reductions are necessarily attributable to these actions. Due to uncertainties, as well as questions about reliability and practicability of monitoring and auditing, upper limits could be established for exposure reductions attributed to on-site controls. For instance, a maximum total allocation of 3 log10 exposure reduction is considered acceptable in non-agricultural recycled water uses within NSW (DPI 2015).
	86	Ingestion associated with use of irrigated parks will be very low. Exposure and ingestion will be even lower where irrigated areas are not used for sporting activities.	Repeated. Remove last paragraph/sentence on page as it is already included in previous paragraph.
Table 3.5	90	Row: Helminth ova	Superscript 'c' should be 'd'
		Table sources	Reference Soller et al (2015), in footnote to Table 3.5, is not included in reference list on pages 153-161 (there is a reference to Soller et al 2016).
Table 3.6	91	Total phosphorus 0..04	Remove additional decimal point
3.5	92	• 8000 infectious viruses (based on infectious adenovirus in lieu of an absence of data **in** infectious norovirus) per L	Change to: • 8000 infectious viruses (based on infectious adenovirus in lieu of an absence **of** data in infectious norovirus) per L
		the target of **1µDALY** for defined uses of recycled water	Change to: the target of **1µDALY pppy** for defined uses of recycled water
3.5.2	95	Second paragraph, reference to Section 3.2.1 and Ottoson and Stenstrom, 2003.	It is stated that the publication Ottoson and Stenstrom 2003 is discussed in Section 3.2.1; however, while it is referred to previously in Section 3.2.1, the study is not discussed in detail, as implied.

Section	Page	Text	Comments
Table 3.8	103		In the last two rows of Table 3.8 (Commercial Food Crops, Non-food crops), in column four, the word 'or' between the last two open dotted points should not have a black dot point marker.
3.5.5	105	Heading	Check heading numbering, section 3.5.5 appears within section 3.6.
		The 2011 Australian Drinking Water Guidelines (NHMRC–NRMMC **2004**)	Change to: The 2011 Australian Drinking Water Guidelines (NHMRC–NRMMC **2011**)
		Fifth line under section 3.5.5, reference to NRMMC et al. **1998**	Change to NRMMC et al. **2008**
Table 5.6	125	Text under Table 5.6	Change to 'Notes' rather than 'Note'.
5.6.1	130	*Standard Methods for the Examination of Water and Wastewater* (APHA, AWWA and WEF **2012**)	Refer to the most recent version of Standard Methods: i.e. *Standard Methods for the Examination of Water and Wastewater* (APHA, AWWA and WEF **2017**)
		2nd paragraph under section 5.6.1	Missing full stop at the end of the paragraph
Appx 2, 2.1	132	Second last sentence of first paragraph under section A2.1	No capitalisation required for 'litre'.
		Published concentrations are derived using PCR based methods. **of published** data from inlets to 42 WWTPs calculated a mean concentration	*Change to:* Published concentrations are derived using PCR based methods. **Published** data from inlets to 42 WWTPs calculated a mean concentration
		Reference to "Jofre and Branch 2009"	The reference "Jofre and Branch 2009" is listed in in the reference list for Appendix 2 as "Jofre and Blanch 2010
	133	Recent data from 8 Australian WWTP showed that sewage contained 3500 **viable oocysts** per litre	Change to: Recent data from 8 Australian WWTP showed that sewage contained 3500 **viable *Cryptosporidium* oocysts** per litre
		A second smaller study of 5 **wastewater treatment plants** conducted in South Australia and Victoria detected an average of 2300 Cryptosporidium oocysts/L with a 95th%ile of 5000 oocysts/L	Change to: A second smaller study of 5 **WWTP** conducted in South Australia and Victoria detected an average of 2300 *Cryptosporidium* oocysts/L with a 95th%ile of 5000 oocysts/L Also note inconsistent use of "oocysts per litre" and "oocysts/L".

Section	Page	Text	Comments
		default value used for Campylobacter (Deere and Khan 2016) **<u>there 10</u>** fold more cases	Change to: default value used for *Campylobacter* (Deere and Khan 2016) **<u>there are 10</u>** fold more cases
Appx 2, 2.2	133	Dot points under section A2.2	Second dot point requires a full stop at the end.
Appx 2, Table A2.2	134	Reference to Teunis et al. 2002	Not included in reference list on pages 153-161. Reference list includes a reference to Teunis et al. 2004.
Appx 2, Table A3.7		Table header	Remove second space between Table and A3.7.
References		AS/NZS (Australian Standard/New Zealand Standard) (2004b)	Remove second space between 'Standard)' and '(2004b)'
		Hellmér M et al reference	Remove second space between 'Provided ' and 'Early Warnings'.
General		norovirus	Change references to "Norovirus" to "norovirus" throughout document. The use of a small "n", or a large "N" for norovirus is used inconsistently throughout the guideline document

Attachment 3: Proposed improvements for helminth egg management in the AGWR revisions: 2020

This technical paper *Proposed improvements for helminth egg management in the AGWR revisions: 2020* was authored by Dr Daryl Stevens (Atura Pty Ltd) and Dr Aravind Surapaneni (South East Water).

The following Australian water utilities contributed to the technical paper:

- Hunter Water
- Icon Water
- Seqwater
- South East Water
- Sydney Water
- TasWater
- Water Corporation

Proposed improvements for helminth egg management in the AGWR Revisions: 2020

By Dr Daryl Stevens and Dr Aravind Surapaneni
(Atura Pty Ltd and South East Water). 28/3/2020.
Contact: daryl@atura.com.au

Consultation on draft revisions to the Australian Guidelines for Water Recycling (AGWR): Managing Health and Environmental Risks (Phase 1), was released for comment on the 31st of January 2020 and the consultation is open until the 31st of March 2020.

Contents

Abbreviations

AGWR	Australian Guidelines for Water Recycling	STP	Sewage treatment plant
ASP	Activated sludge plants	WHO	World Health Organisation
CB	Cysticercus bovis	LRV	Log_{10} Reduction Value
HE	Helminth eggs	PCE	Percentile
HRT	Hydraulic retention time	UV	Ultra-violet
QMRA	Quantitative microbial risk assessment	WWTP	Wastewater treatment plant

1 Summary

In the draft revision of the Australian Guidelines for Water Recycling (AGWR), the management of helminth eggs in sewage to produce recycled water does not utilise a risk-based approach that considered the actual risks experienced across Australia. The draft revision adopts guidelines and management practices based on exposure scenarios in countries where helminth infections are endemic. In Australia, where helminth infections are generally not endemic, this approach leads to excessive treatment requirements and over management of the associate risk. The AGWR should adopt a risk-based approach to the management of helminth eggs in the production of recycled water that is consistent with the management of health risks from other pathogens in the guidelines.

Historically, there has been no driver to adopt a true risk-based approach to the management of helminth eggs due to several factors: a) the risks have generally been easy to manage via lagoon systems, b) the consequences are relatively low in a develop country compared to other human pathogens, and c) there has been a limited need for a scientific assessment of the risks in a country where helminth infections are not endemic. These factors are changing as the population in Australia changes. Over the last eight years there have been several research projects in Australia to assess helminth egg numbers in sewage, the helminth egg risks in recycled water and the identification of better management strategies.

The AGWR draft needs to be updated to adopt a risk-based approach to the management of helminth eggs to produce recycled water in Australia. In summary, our observations and recommendations that should be considered in the AGWR are:

1. That a set 4.0 $\log_{10}$ reduction value (LRV) or 25 days lagoon hydraulic retention time (HRT) should not be to manage the risk from helminth eggs (HE) in sewage when cattle are exposed. This guidance was developed more than 30 years ago for countries where helminth infections are endemic and the HE concentration in sewage ranged between 100 and 2000 HE/L. Sewage in southern Australia typically has <1.0 HE/L. In other parts of Australia, where there are good sanitation, hygiene and chemotherapeutic treatment of helminth infections (i.e. good preventative practices), there is expected to be < 2.0 HE/L in sewage. Concentrations may be higher in some tropical areas where soil-transmitted helminths exist and good preventative practises are difficult to maintain.
2. A similar approach to the World Health Organisation (WHO) should be taken in the AGWR for the management of HE concentrations in sewage. The WHO Guidelines for Wastewater Reuse in agriculture (Appendix 6.1) defined and adopted a risk-based approach to the management of HE in sewage based on the concentration of HE measured in sewage.
3. In several regions of Australia, where the average concentration of HE in sewage has been well documented to be <1.0 HE/L, the LRV and corresponding lagoon HRT to manage the risk to humans and livestock can safely be reduced to 3.0 LRV and 18 days lagoon HRT (Low level of design and management system). The 3.0 LRV considers outbreak loads of HE loads intermittently entering sewage treatment plants (STPs).
4. A summary table is proposed that provides the HE LRVs that are acceptable for activated sludge plants (ASP) and non-aerated lagoon treatment trains that either a Low or High level of design and management.
5. In much of Australia, the application of a 4.0 LRV or 25 days lagoon HRT to produce recycled water for livestock use is far too conservative. It imposes unnecessary costs for the ongoing use of recycled water in Australia, with no significant benefit to human or animal health.
6. On-farm controls should also be considered when achieving LRV requirements.

The draft revisions proposed are for Chapters 1, 2 3 and 5 in Phase 1 of the AGWR (NRMMC *et al.*, 2020). Helminth egg management is a fundamental part of Chapter 3 and should be consider and include the revisions proposed in this public comment below.

2 Background and helminth concentrations

2.1 Helminths of interest

When recycling water from sewage there are several helminths of interest (Table 2-1). The helminth life-cycled and exposure pathway are often unique to the risk they pose in recycled water (Figure 2-1). There are also various control measures in the helminth's lifecycle not under the control of the water recycling process (Appendix 6.2) which help facilitate disruption of the helminth life-cycle. These control measures help ensure the related diseases in intermediate and definitive hosts are controlled in Australia and minimise the likelihood of infection, the intensity and consequence from infection. However, exposure of pigs to recycled water directly or via produce grown with it is generally not allowed in Australia due to the potential severe consequences of neurocysticercosis.

Table 2-1 Helminths of interest, associated diseases and exposure pathways when recycling water from sewage in Australia.

Helminths	Disease	Disease term	Exposure pathway (EP)
Ascaris lumbricoides (Human roundworm)	Mature *A. lumbricoides* parasitising the human intestine	Ascariasis	EP1
Trichuris trichiura (Human whipworm)	Mature *T. trichiura* parasitising the human large intestine	Trichuriasis	Similar to *Ascaris* (EP1)
Taenia solium (Pork tapeworm)	Larval cysts from *T. solium* forming in human tissue	Human cysticercosis or neurocysticercosis	EP2
	Larval cysts from *T. solium* forming in pig tissue	Porcine cysticercosis	EP2
T. saginata (Beef tapeworm)	Larval cysts (cysticerci) from *T. saginata* forming in cattle tissue, if infected meat is consumed by humans, cysticerci will form in the human host	Bovine cysticercosis, *T. saginata* cysticercus, Cysticercus bovis (CB) (Beef measles)	EP3a
T. saginata or *T. solium*	Mature *T. saginata* or *T. solium* parasitising the human intestine	Taeniasis	EP3b, EP2

Based on the Australian Guidelines for Water Recycling (NRMMC et al., 2006). EPs are in described in Figure 2-1.

Ascaris is often used as the reference helminth as it is the most common helminth infecting humans and the eggs are known to be relatively persistence in the environment.

In addition to the helminths of concern identified in Table 2-1, the helminths *Ancylostoma duodenale* and *Strongyloides stercoralis* are commonly found in humans in the north-west of Western Australia (Pers.comm. Water Corporation, WA). *S. stercoralis* is a roundworm where larva and not egg are excreted in the stool and therefore is not a concern for recycled water as the larvae are easily destroyed in the treatment process. However, *A. duodenale* is a hookworm and infects humans through penetration of the skin by the larva, and eggs are released in the stool and should therefore be managed in recycled water. These observations highlight that above the 20th parallel, in some remote communities, the reference helminth of concern may not be *Ascaris* and other helminths known to be of interest should be considered as a part of the risk management plan.

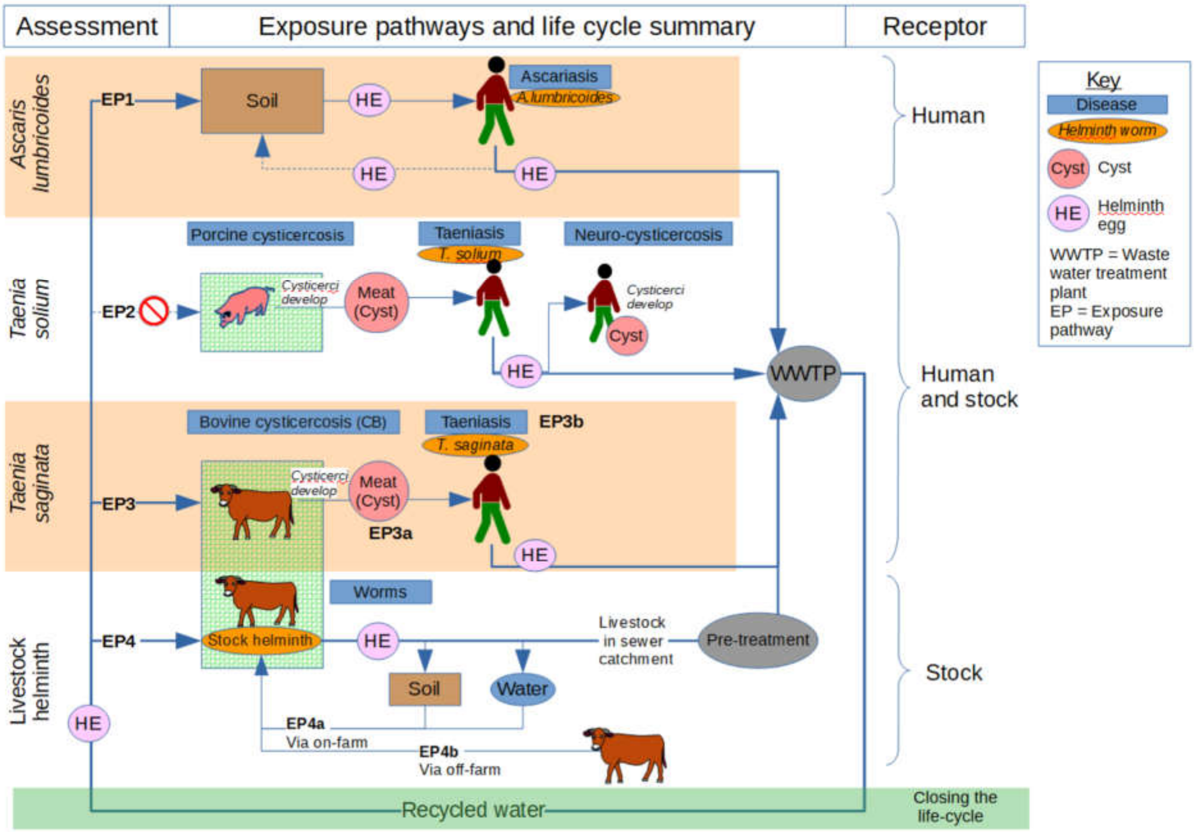

Figure 2-1 Helminth life cycles potentially completed via the production and use of recycled water, and related human and animal diseases (Stevens et al., 2020) submitted.

2.2 Concentrations of helminth eggs in sewage in Australia

The average concentration of helminth eggs of concern in sewage in southern Australian is <1.0 HE/L, and in several cases <0.1 HE/L (Table 2-2). Stevens *et al.* (2020) found that from 554 sewage samples collected from 11 wastewater treatment plants (WWTPs) in southern Australia over a ten-year period only 5 *Ascaris* eggs and no *Taenia* eggs were detected. The adjusted baseline (average) numbers of *Ascaris* and *Taenia* eggs were estimated to be approximately 0.03 and 0.003 HE/L, respectively. The WWTPs that were a part of this study varied in size from 1 to 500 ML/day, representing the various sizes of WWTPs found across Australia.

Discussion with several water utilities across Australia indicated that HE concentrations in sewage from northern parts of Australia is limited. However, the HE concentrations in sewage are typically considered to be below the limit of detection (Table 2-2). Further work is needed to investigate the concentration of HE in sewage from northern Australia; however, results from southern states are conclusive on the low HE concentrations in sewage.

Table 2-2 Average helminth egg concentrations in sewage, effluent, recycled water and biosolids from sewage treatment plants in Australia.

State	Total HE in sewage (HE/L) *Ascaris*	*Taenia*	Total HE in recycled water of effluent (HE/L)	Total HE in biosolids (HE/g dw)	Comment
SA	nm	nm	nm	<1.0	As none in biosolids, none are assumed in influent. Pers.comm. SA Water.
Vic	<0.1 [A]	<0.01	<0.1	<1.0	Stevens 2020. Several water utilities and WWTP (South East Water, Melbourne Water, Coliban Water)
NSW	<0.1	<0.01	<0.1	--	Pers.comm, Sydney Water (nm); data from Hunter Water.
Qld	nm	nm	<1.0	--	Pers.comm. (nm), SEQ Water;, Urban Utilities data in recycled water.
WA	<1.0	nm	<1.0		2014 -15 study [B]
Tas	nm	nm	nm	nm	Pers. comm. Tas Water.
ACT	nm	nm	nm	<1	Pers.comm. Iconwater
NT	nm	nm	nm	nm	no response

nm = not measured, -- = not data supplied

[A] A Comprehensive analysis is Victoria indicate that Ascaris eggs are found occasionally,

[B] There is limited data below 20th parallel –State-wide sampling in 2014-15 showed low risk below 20th (from memory detects were not consistent or frequent). pers.comm . Water Corporation

3 Helminth egg reduction requirements

Currently, the AGWR specify that to manage the risks associated with HE in sewage for the use of recycled water with cattle (i.e. livestock drinking, pasture, fodder, hay) a lagoon HRT of 25 days or a HE LRV of 4.0 is required. Due to population growth in many regions of Australia, several lagoon-based treatment systems will soon not be able to achieve this HRT.

Recent research utilising quantitative microbial risk assessment (QMRA) and other risk-based assessments has shown that to manage helminth related risk a range of LRVs can be used to manage the helminth species of concern (Table 2-1), based on the concentration of HE in the influent (Table 2-2) and the exposure scenario (Table 3-1). The research also considered possible peaks from the baseline HE concentrations resulting from worst case events *e.g.*, disease outbreaks or importation. In these scenarios, suitable management of helminth eggs in sewage that is protective of outbreaks could be achieved by an LRV of 2.0 to 3.5, based on the sewage HE concentration considered and exposure scenario (Table 3-2).

Table 3-1 Log$_{10}$ reduction values (LRV) determined for helminth species of interest in sewage for production of recycled water.

Helminth species	Helminth eggs (HE/L) in sewage in Southern Australia			Guideline value for recycled water (HE/L)	Guideline recommen-dations from	LRV required	Comment
	Meas -ured	Prob-ably	Out break				
***Ascaris lumbricoides* (human roundworm)**	<1.0	<0.05	10	<0.1 <1.0	(WHO, 2006) (Stevens et al., 2017)(QMRA)	**2.0** **1.0 - 2.0** **2.6 to 3.0**	Based on achieving guideline value Appendix 6.1 below. Assuming lower HE numbers. Protective of outbreaks. Rounded up to 3.0 to be equivalent to the that for T. saginata
***Trichuris trichiura* (human whipworm)**		nd		--	--	**--**	Managed by managing Ascaris.
***Taenia solium* (pork tapeworm)**		nd		Exclusion of use	not applicable	**--**	Managed by preventing exposure.
***T. saginata* (beef tapeworm)**	nd	<0.003	1.0	--	(Stevens et al., 2017) (Stevens et al., 2020) (QMRA)	**3.0** **1.6** **3.0 to 3.5**	Worst case scenario. Baseload. Outbreak [A].
Fasciola hepatica		nd		--	(Stevens et al., 2017)	**3.0**	Worst case scenario.

[A] Small wastewater treatment plants (WWTP) (≤ 2 ML/day flow) require a larger LRV (3.5) for *T. saginata* outbreak protection, where large WWTP (>2 ML/day flow) required an LRV of 3.0.
-- = none. nd = no data.

The LRV recommendations in Table 3-1 are sourced from three recent publications that have improved our knowledge of the risk from HE in sewage in Australia (where helminth infections are not endemic) (Stevens *et al.*, 2017, 2020; Kiermeier *et al.*, 2019). They also consider the LRVs published in the WHO guidelines (Appendix 6.1) for the protection of human health (WHO, 2006). A risk-based approach is proposed for determining the LRV for HE control in sewage based on the HE concentration of *A. lumbricoides* (or other dominant helminth species in a specific region) as an indicator of the helminth burden in the human population (Table 3-2). It is worth noting, that if the WHO recommendations for the protection of human health were followed (Appendix 6.1) a concentration of <1 HE/L would not require any further LRV to achieve the recommended guideline limit of < 1.0 HE/L. This makes the proposed LRVs (Table 3-2) over protect for the baseline, yet ensures any future outbreaks or importations of HE will be managed at detectable concentration, so HE concentrations can be used for a trigger points for further investigation.

The LRVs proposed in Table 3-2 considers the recent research and helminths of interest outlined in Table 2-1 and Figure 2-1. In summary, a comprehensive risk assessment for *Ascaris* and human exposure has indicated that an LRV of 2.6 is protective of an outbreak of disease and more than sufficient to achieve the health-based target of 1 µDALY for *Ascaris* (Table 3-1) (Based on the median of 2.1 HE/L and a maximum of 10 HE/L). By conservatively using a HE concentration of 1.0 HE/L and a LRV of 3.0, human health is protected, with a 2 LRV safety buffer, if the:

- average concentration of HE in sewage is ≤ 1.0 HE/L
- WWTP consistently achieves a 3.0 LRV

Where the average HE concentration for the species of interest or relevant to the region (Table 2-1) exceeds 1.0 HE/L then an LRV of 4.0 is required or a site-specific risk assessment undertaken to protect human health (this also applies if the 95th percentiles indicated is exceeded; Table 2-1).

To minimise the risk of cysticercus bovis in cattle (from cysts of *T. saginata*) an LRV of 3.0 has been estimated to be protective of an outbreak of disease (Table 3-1) for a larger WWTP (> 2 ML/day) where the average concentration *Taenia* eggs is < 0.1 HE/L. Because of the possibility of higher concentrations of HE in smaller WWTPs (≤2 ML/day) during an outbreak of disease, an LRV of 3.5 was determined to be protective of cattle meat quality. It is worth noting that that these protection levels are two orders of magnitude below many other developed countries (Stevens et al., 2020).

Table 3-2 Proposed risk-based LRV requirements for HE management in sewage.

	WWTP size	Average (95th PCE) helminth egg concentration (HE/L) [A]			Comment
		<0.1 (<1.0)	**0.1 to ≤ 1.0 (<2.0)**	**> 1.0 (<10)**	
Protection of human health					
LRV required	> 2 ML/day	2.0	3.0	4.0	A 3 LRV buffer to protect against outbreaks from baseloads and recognises higher risk from small treatment plants when outbreaks
	≤ 2 ML/day	3.0	3.0	4.0	
Protection of cattle [B]					
LRV required	> 2 ML/day	3.0	3.5	4.0	Recognises higher risk from small treatment plants when outbreaks
	≤ 2 ML/day	3.5	4.0	4.0	

HE = Helminth egg, LRV = Log reduction value, WWTP = Wastewater Treatment Plant.

[A] Based on *Ascaris lumbricoides* as an indicator of helminth infection in the populations. If other helminths of concern for recycled water use are known to have higher concentrations, these should be used as the indicator. If HE concentrations exceed the 95th percentile (PCE) stated in parentheses, the LRV required should be reassessed. For example, if samples are taken monthly and more than 2 samples in a 12 month sampling period exceed the influent concentration specified for the LRV.

[B] If *Taenia* spp are detected in influent > 1 HE/L in more than 1 sample/year using a monthly sampling and analysis strategy. Supply should be ceased to cattle and investigates undertaken to address the *Taenia* spp source in the influent.

4 Methods for achieving the LRV required

The following section details how the LRVs required to manage the risk from HE in sewage could be achieved by:

- treatment, or
- on-farm controls.

4.1 Removal of helminth eggs by treatment

Reduction of helminth from sewage is achieved through three main processes at the treatment plant:

1. removal of solids with HE attached,
2. settling, as HE have a greater density than water, and
3. filtration, as HE are larger compared to other pathogens > 25 μm minimum diameter.

The three main treatments above can be achieved by:

1. activated sludge plants (ASP)
2. lagoons, and
3. filtration.

The HE is relatively thick and multilayered and resistant to chlorine and ultraviolet (UV) disinfection and so these types of treatment are generally not effective at cost effective doses. Both the activated sludge and lagoon processes effectively rely on the settling of sludge and HE and meeting design requirements to achieve the LRV.

The effectiveness of these treatment processes relies on how well operated and maintained the treatment systems are. Recently updated design equations to achieve the LRV required for HE control by treatment have been proposed that can be used for treatment plants where the design and management are considered to be either a low or high standard (Table 4-1).

Table 4-1 Log reduction values (LRV) credits for hydraulic retention times (HRT) in lagoon systems and activated sludge plants (ASP)

Treatment system	Level of design and management of the treatment system level		LRV Credit
	High [A]	Low [B]	
Lagoon system	HRT	HRT	LRV
	12	14	2.0
	14	16	2.5
	16	18	3.0
	18	21	3.5
	20	23	4.0
ASP	HRT	HRT	LRV
	0.41	0.70	0.5
	0.60	0.88	1.0

[A] A high level of design and management would include a lagoon system designed and operated to promote HE removal. i.e. not aerated, a number of lagoons in sequence, appropriate weirs between lagoons, inlets and outlets at a maximum distance apart, limited sludge build-up, so the operated volume is within 95% of design volume, well controlled, managed and monitored hydraulic retention times (HRT), etc. For activated sludge plants (ASP), a high level of design and management should include continuous monitoring of operational performance within the design specifications, with the use of critical control points, if required. [B] A low level of design would be considered where the high level and management is not achieved or not well understood. Based on Stevens et al. (2020).

Filter systems require specific validation for HE removal and the relevant approvals from the regulators. Appropriately designed sand filtration systems can typically achieve HE LRVs of:

- between 1 and 2, and
- between 2 and 4 with coagulation.

These LRVs depend on the process type and parameters. One common and conservative solution to allocating an LRV to a filtration system in water recycling schemes, that use more advanced treatment systems than just ASPs or lagoons, has been to adopt the LRV associated with protozoan parasites (usually *Cryptosporidium* oocysts) and assuming that HE behave similarly (NRMMC et al., 2006).

4.2 Onsite controls

The following onsite controls can achieve additional HE LRVs for cattle exposure:

- A 1.5 LRV credit can be obtained if cattle do not have access to drinking recycled water directly, and this can be enforced and monitored. For example, hay produced with recycled water and feed to cattle with no recycled water access.
- A 0.5 LRV credit can be obtained if cattle will be exposed to paddocks irrigated with recycled water for only a short period in their lifetime (<6 months) and HE concentrations average < 0.1 HE/L in raw sewage.

4.3 Practical use of the proposed LRV required for HE control

Table 4-2 details some examples of the LRV required for a specific use scenario and WWTP, and how this can be achieved with treatment and on-farm controls.

Table 4-2 Consideration of exposure scenarios and the LRV required and achieved for HE control in sewage

Consideration	Unit/type	Cattle WWTP-A		Cattle WWTP-B		Human WWTP-C		Reference
LRV required								
Average HE concentration in sewage (95th percentile)	HE/L	≤1.0 (<2)		≤1.0 (<2)		≤0.1 (<1)		**Table 3-2**
WWTP sewage flow (ML/day)	ML/day	5		1		20		
	Total LRV required	**3.5**		**4.0**		**2.0**		**Table 3-2**
LRV achieved by treatment and on-farm restrictions								
		HRT (d)	LRV	HRT (d)	LRV	HRT (d)	LRV	
LRV achieved Treatment								
ASP	Low			0.3	**0**			Table 4-1, Section 4.1
	High	0.45	**0.5**			0.43	**1.0**	
Lagoon	Low	16	**2.5**					
	High			20	**4.0**	12	**2.0**	
Filtrations (as validated)			n/a		n/a		n/a	Section 4.1
LRV achieve on-farm restrictions								
Cattle have no access to drinking recycled water			**1.5**		n/a		n/a	Section 4.2
Cattle will have < 6 month of exposure to recycled water (sewage <0.1 HE/L)			n/a		n/a		n/a	Section 4.2
	Total LRV achieved		**4.5**		**4.0**		**3.0**	Summed
LRV balance (must ≤ 0)			-1.0		0		-1	Required-achieved
Management of HE achieved			Pass		Pass		Pass	

5 Conclusion and recommendations

The current draft of the AGWR has no consideration of the inherent risk of HE exposure from recycled water and is not suitable for many exposure scenarios across Australia. Use of these guidelines proposed in a country not endemic with helminths is over-protective and the AGWR need to adopt a genuinely risk-based approach to helminth egg management, without compromising human or livestock health. Such an approach will help ensure human and animal health protection is maintained and ensure costs of over-treatment do not lead to inhibition of water recycling, preventing its ongoing adoption and use.

Our recommendation is to improve the risk management of HE in sewage so that it reflects the Australian context and our current understanding of the risks in a country where helminth infections are not endemic. Dr Stevens and his research associates are willing to draft the required text and changes to the AGWR to facilitate this improvement.

6 Appendix

6.1 World Health Organisation guidance on Microbial reduction targets for helminth eggs

From page 26 (WHO, 2006)…

> "The required helminth egg reduction to achieve the target of <1 egg per litre depends on the number of eggs in the raw wastewater. For example, if there are 10^3 eggs per litre in the raw wastewater, the required reduction is 3 log units; if there are 10^2, the required reduction is 2 log units; and if there are 10^1, the required reduction is 1 log unit (Table 4.4). Wastewater treatment processes that achieve, or partially achieve, these log unit reductions are described in chapter 5. If the number of helminth eggs in untreated wastewater is <1 per litre, then no additional health protection measures are required, as the target value is automatically achieved (this is the typical situation in most industrialized countries).
> Table 4.4 shows examples of options for the reduction of helminth ova by two health protection measures and their associated verification requirements."

Table 4.4 Options for the reduction of helminth eggs by health protection measures for different helminth egg numbers in untreated wastewater and associated verification requirements

Health protection measure	Number of helminth eggs per litre of untreated wastewater	Required helminth egg reduction by treatment (log units)	Verification monitoring level (helminth eggs per litre of treated wastewater)[a]	Notes
Treatment	10^3	3	≤1	Treatment should be shown to achieve this egg quality reliably (see also Box 5.2).
	10^2	2	≤1	
	10	1	≤1	
	≤1	0	N/A	The target of ≤1 egg per litre is automatically achieved.

6.2 Helminths relevant to recycled water product and control measures for management of disease and infection

Table 6-1 Helminths relevant to the use of recycled water and other livestock related diseases, symptoms.

Infection route and species	Infection pathway	Disease	Symptoms[B]	Control measures
1. Human to Human route				
***A. lumbricoides*[C]**	Human → Soil → Human	Ascariasis (large roundworm parasitising the human intestine)	Often no symptoms, if occurs, light abdominal discomfort. Severe infections impair child growth and can cause serious health complications e.g. intestinal blockage	• *Cryptosporidium* used as a surrogate in AGWR • Medication available to treat • Most refugees, asylum seekers and migrants medicated prior to entry into Australia[D], or subject to medical examination
***Trichuris trichiura*[C]**	Human → Human	Trichuriasis (whipworm infection; *Trichuris* is also a roundworm)	Light or heavy infections (painful passage of stool). Heavily infected children show anaemia, growth retardation and impaired cognitive development	
2. Human to livestock or Human to livestock to human route[A]				
T. saginata	Human faeces → Cattle	Cysticercosis bovis (Beef Tapeworm)	Causes small cysts in the muscles of cattle and their presence can lead to all or part of the carcass being condemned	• > 25 day retention in waste stabilisation pond or equivalent[A,E] • Meat inspection • Medication available to treat • Cooking and freezing of meat [F]
	Human faeces → Cattle meat (raw) → Human	Taeniasis	Mild or non-existent, can cause digestive problems including abdominal pain, loss of appetite, weight loss, and upset stomach	• As above
T. solium	Human faeces → Pig	Cysticercosis (Pig Tapeworm)	Causes small cysts in the muscles of pig and their presence can lead to all or part of the carcass being condemned	• Not stated, below assumed
	Human faeces → Pig meat (raw) → Human faeces → Human	Neurocysticer-cosis	Mild or non-existent, but can lead to seizures and muscle or eye damage	• Prohibition on the use of recycled water for pig fodder or drinking water for pigs • Meat inspection • Cooking and freezing of meat [F]

[A]Australian Guidelines for Water Recycling (AGWR)(NRMMC *et al.*, 2006). The AGWR also state that lactating dairy cattle should be excluded from irrigation areas till dry and not used for washing milk machinery.
[B] www.cdc.gov and Filmer (2012).
[C]The protozoa *Cryptosporidium parvum* was used as a surrogate for human infecting Helminths in the AGWR (NRMMC *et al.*, 2006).
[D]Hanieh *et al.* (2016) and www.border.gov.au/Trav/Visa/Heal/meeting-the-health-requirement/health-examinations.
[E]Based on the model described Ayres *et al.* (1992) with no guidance on what constitutes equivalent value.
[F]Kiermeier et al.(2019)

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