Potable Reuse – a Safe, Secure & Sustainable Water Supply Option

Ian B Law

Principal, IBL Solutions

Presentation at SIWW 2022 Conference
20th April 2022

Been there, done that.

"Every glass of water you pour - whether it is coming from an Evian bottle, a filtered refrigerator spigot, or the kitchen tap - has a rich history... in the larger context, whichever place you find least appealing to imagine your water, well your water has been there. More than once. That's not gross. In fact, it points up two central facts about water:

1. Water can be cleaned, always
2. Water can't be used up

The Big Thirst Charles Fishman, 2019"

Topics we'll discuss

- We have the regulations and guidelines to ensure we produce a water (*Purified Recycled Water*) that can be safely added to our drinking water supplies (aka *Potable Reuse*);
- Many communities around the world are already doing this !
- We have proven treatment technologies & systems to produce this water – and each should be considered on its merit for each application;
- Long term sustainability considerations should be included in any assessment;
- PRW applications in inland areas come with hurdles that can influence the treatment train selection.

Sundry Reports & Papers

National Water Research Institute

AN NWRI WHITE PAPER

Direct Potable Reuse: Benefits for Public Water Supplies, Agriculture, the Environment, and Energy Conservation

Prepared by:
Edward Schroeder, George Tchobanoglous, Harold L. Leverenz, and Takashi Asano
Department of Civil and Environmental Engineering
University of California, Davis

Direct Potable Water Reuse for Sustainable Water Supply

Direct potable water reuse offers a number of advantages over the more widely accepted indirect potable water reuse when evaluating alternative water sources. However, it is quite an uphill task to change the strong belief in the benefits of inserting an environmental buffer such as reservoirs before potable use.

By Stuart J Khan and Sarah L Herbert

Mainstreaming Potable Water Reuse in the United States:
Strategies for Leveling the Playing Field

EPA United States Environmental Protection Agency · ReNUWIt · Johnson Foundation

April 2018

reuse and recycling

THE CASE FOR DIRECT POTABLE WATER REUSE IN AUSTRALIA

Stuart J Khan

presented at ozwater'11

refereed paper

THE FUTURE DIRECTION FOR POTABLE REUSE

I B Law

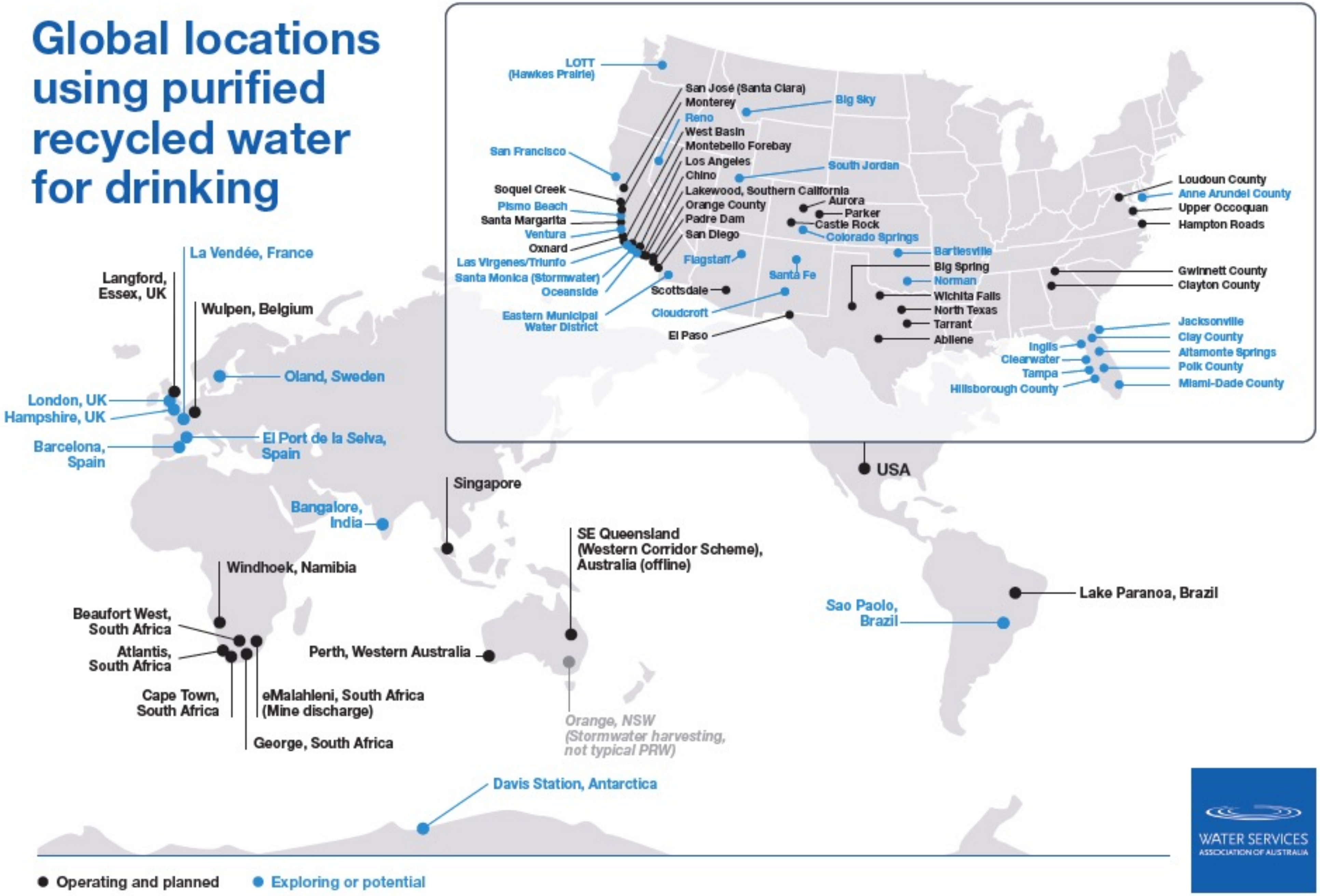
Abstract

…perience from existing IPR schemes …and the development of National …delines that define the issues that …ust be addressed for advanced reuse …chemes lay the foundation for safe …eliable and cost effective alternatives for augmenting drinking water supplies. However, the key requirements for

Direct potable reuse may have lower environmental footprint than indirect potable reuse.

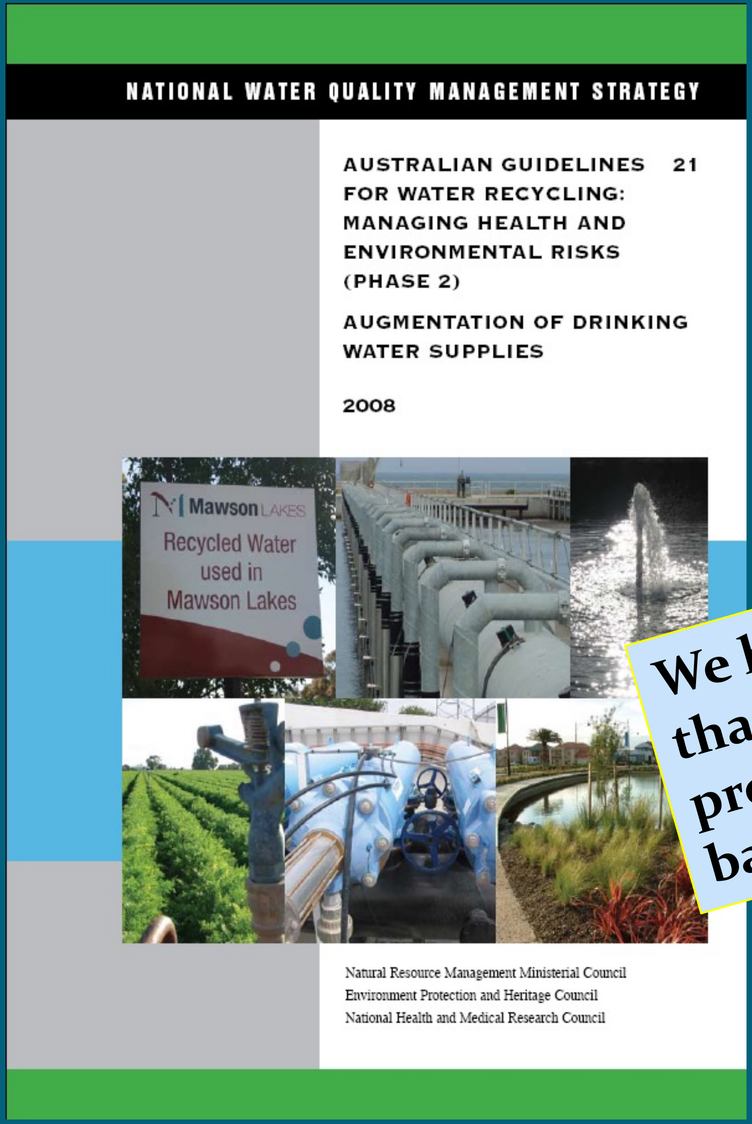
- Advanced treatment processes such as reverse osmosis and advanced oxidation are highly effective barriers to recently identified chemicals of concern such as pharmaceutically active compounds, steroidal hormones and chemicals such as Nitrosodimethylamine (NDMA) and 1,4-dioxane.

Global locations using purified recycled water for drinking



WATER SERVICES
ASSOCIATION OF AUSTRALIA

2008


NATIONAL WATER QUALITY MANAGEMENT STRATEGY

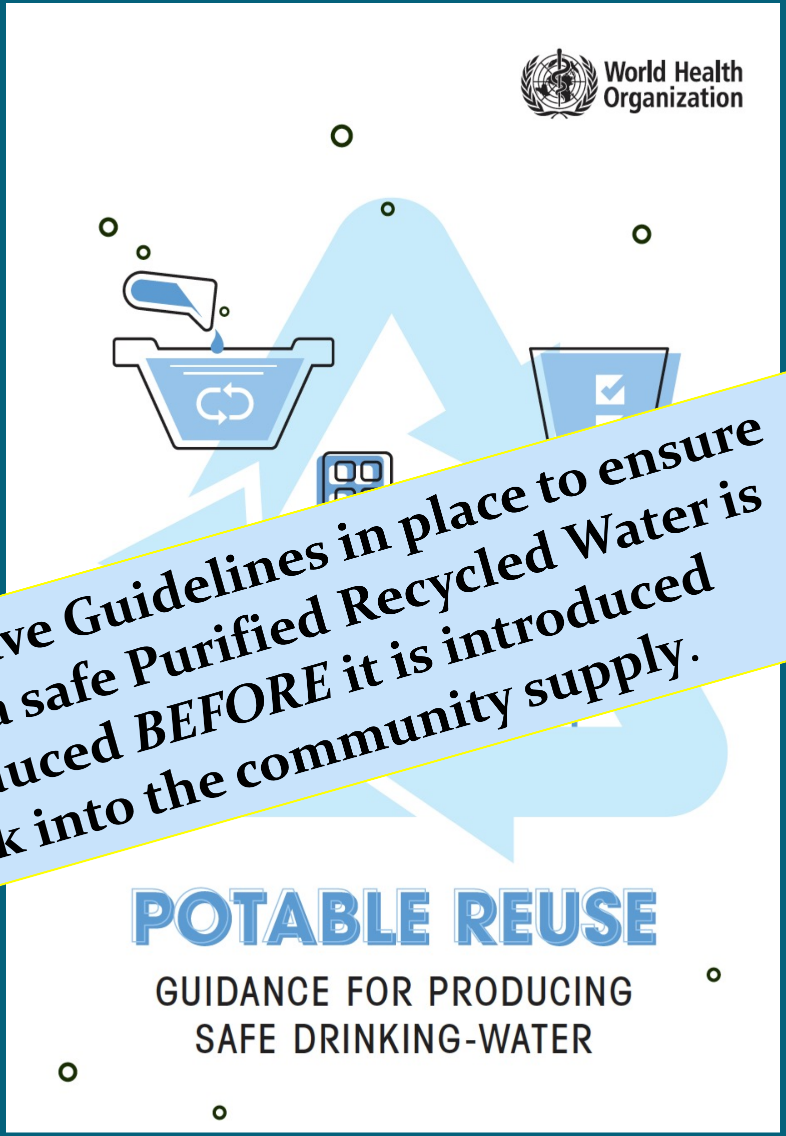
AUSTRALIAN GUIDELINES FOR WATER RECYCLING: MANAGING HEALTH AND ENVIRONMENTAL RISKS (PHASE 2) 21

AUGMENTATION OF DRINKING WATER SUPPLIES

2008

Natural Resource Management Ministerial Council
Environment Protection and Heritage Council
National Health and Medical Research Council

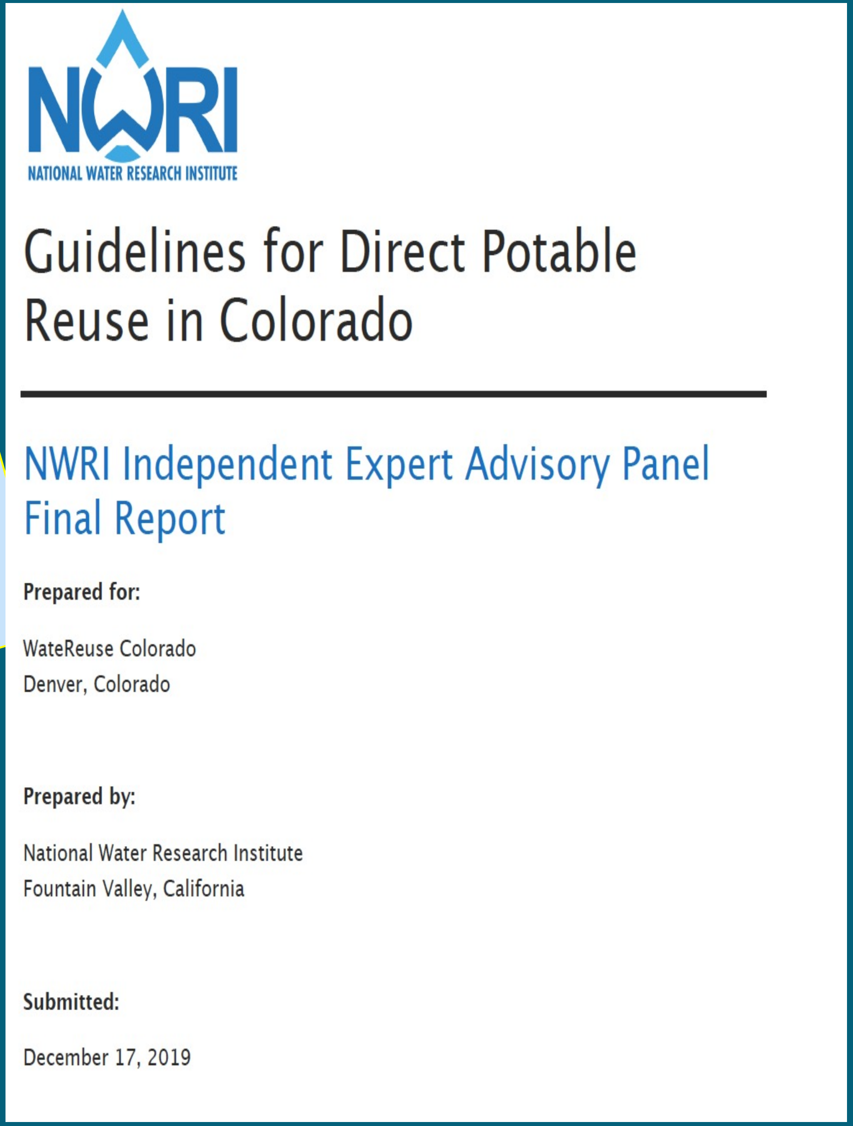
2017


World Health Organization

POTABLE REUSE

GUIDANCE FOR PRODUCING SAFE DRINKING-WATER

2019


NWRI
NATIONAL WATER RESEARCH INSTITUTE

Guidelines for Direct Potable Reuse in Colorado

NWRI Independent Expert Advisory Panel Final Report

Prepared for:

WateReuse Colorado
Denver, Colorado

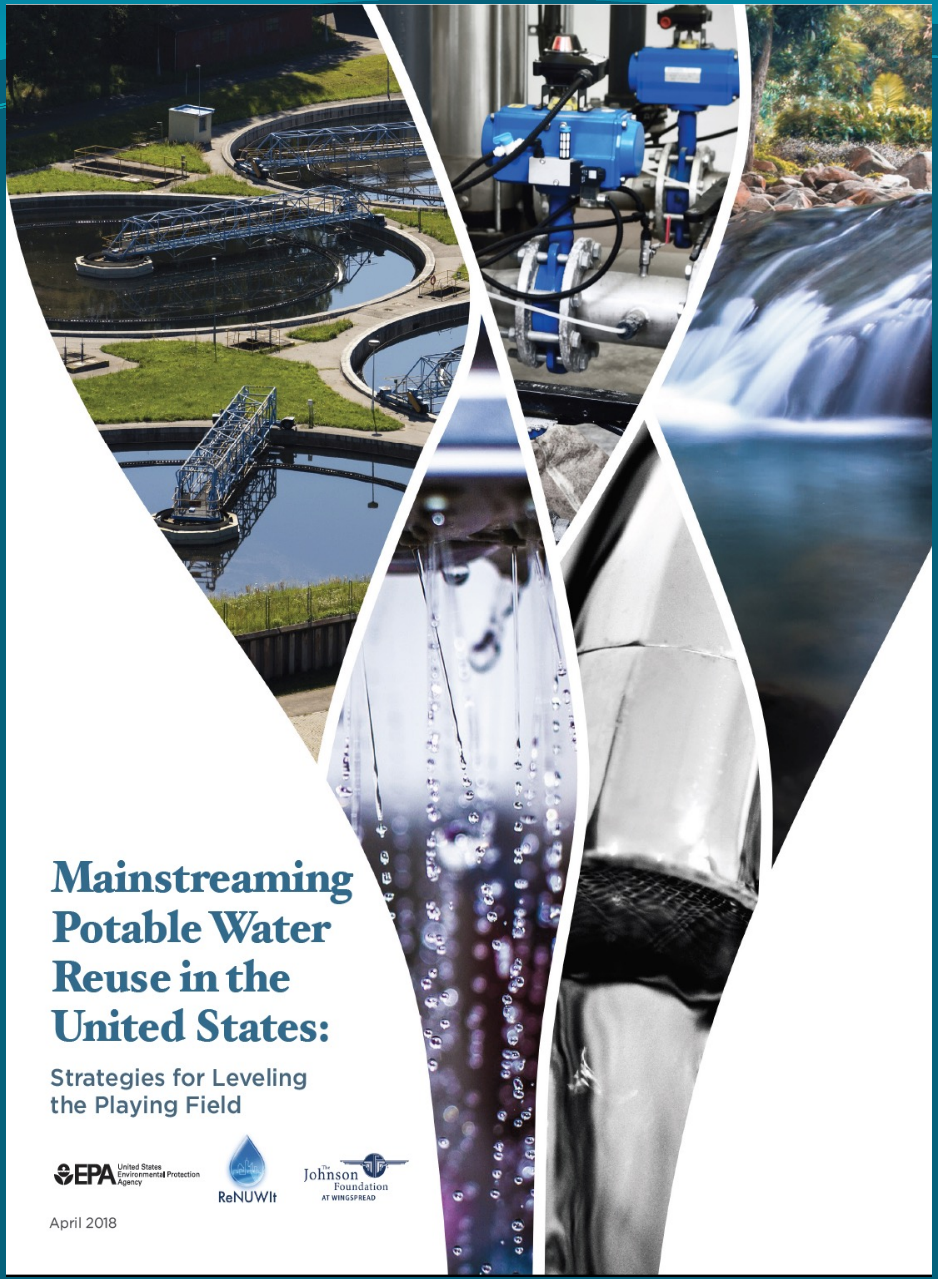
Prepared by:

National Water Research Institute
Fountain Valley, California

Submitted:

December 17, 2019

We have Guidelines in place to ensure that a safe Purified Recycled Water is produced *BEFORE* it is introduced back into the community supply.

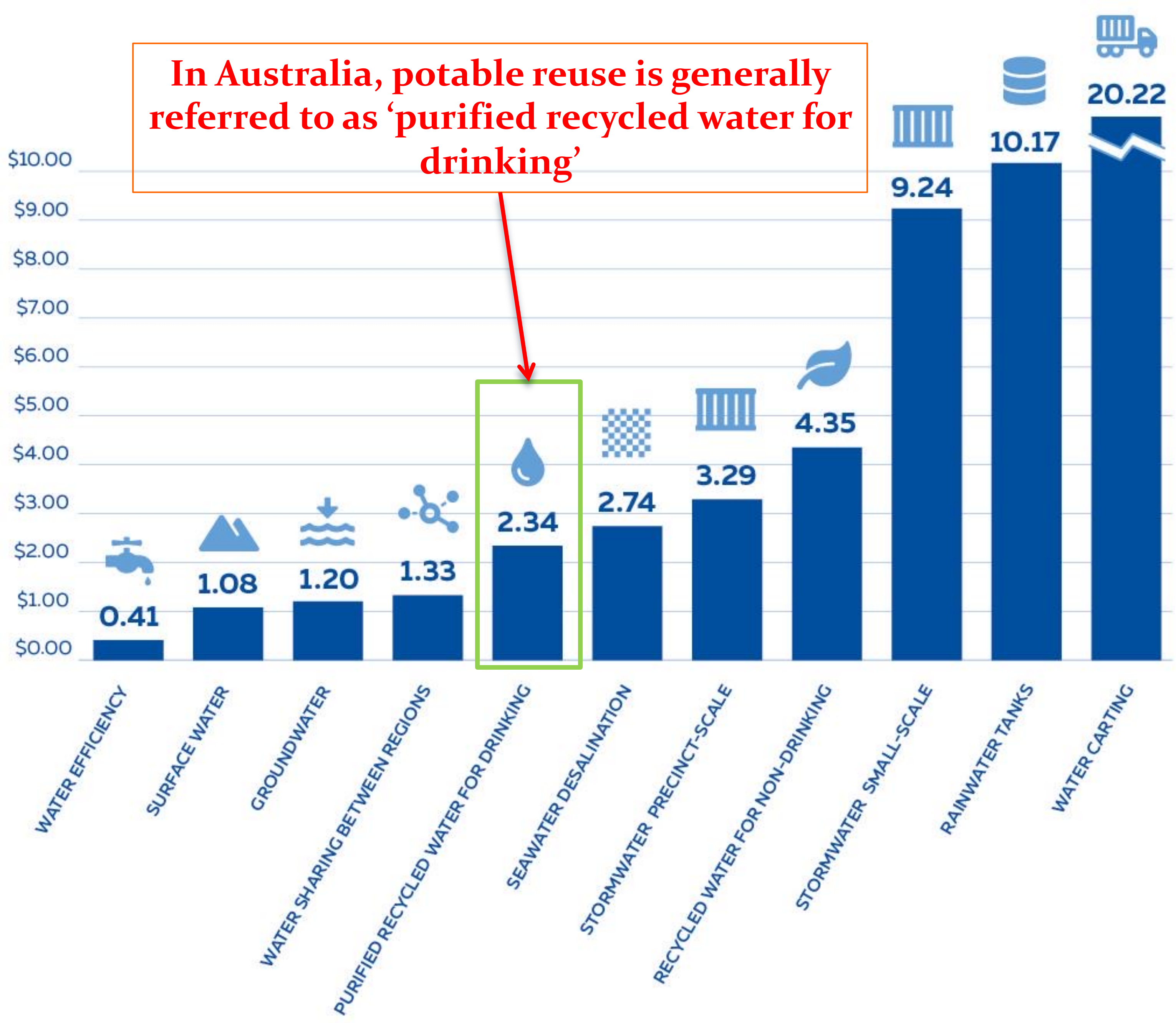


https://www.epa.gov/sites/production/files/2018-04/documents/mainstreaming_potable_water_reuse_april_2018_final_for_web.pdf

August 2020

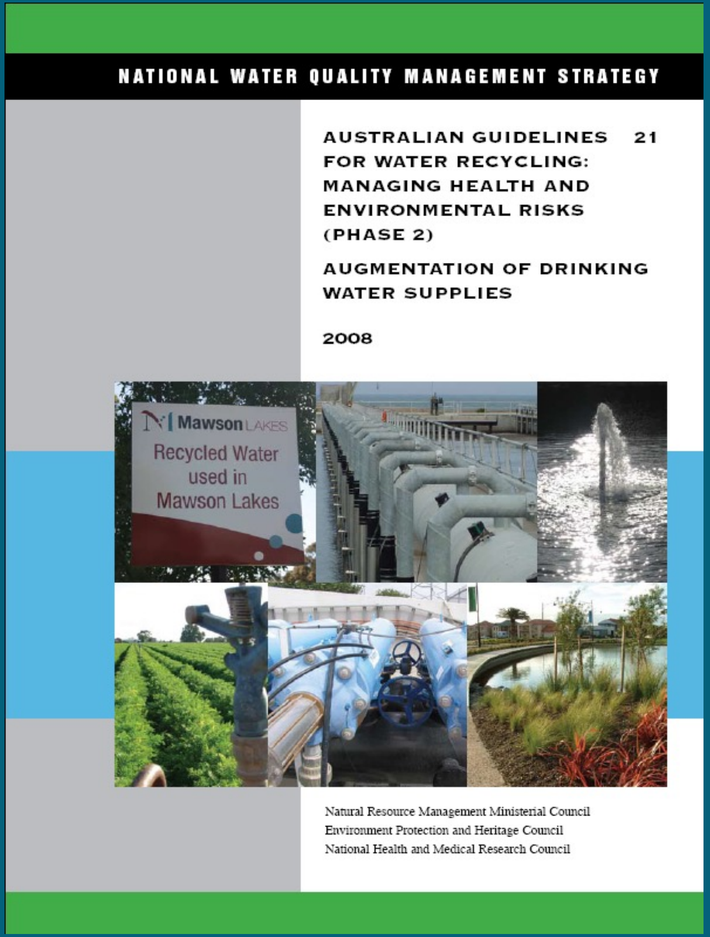
In Australia, potable reuse is generally referred to as ‘purified recycled water for drinking’

Levelised $/KL 2019-20



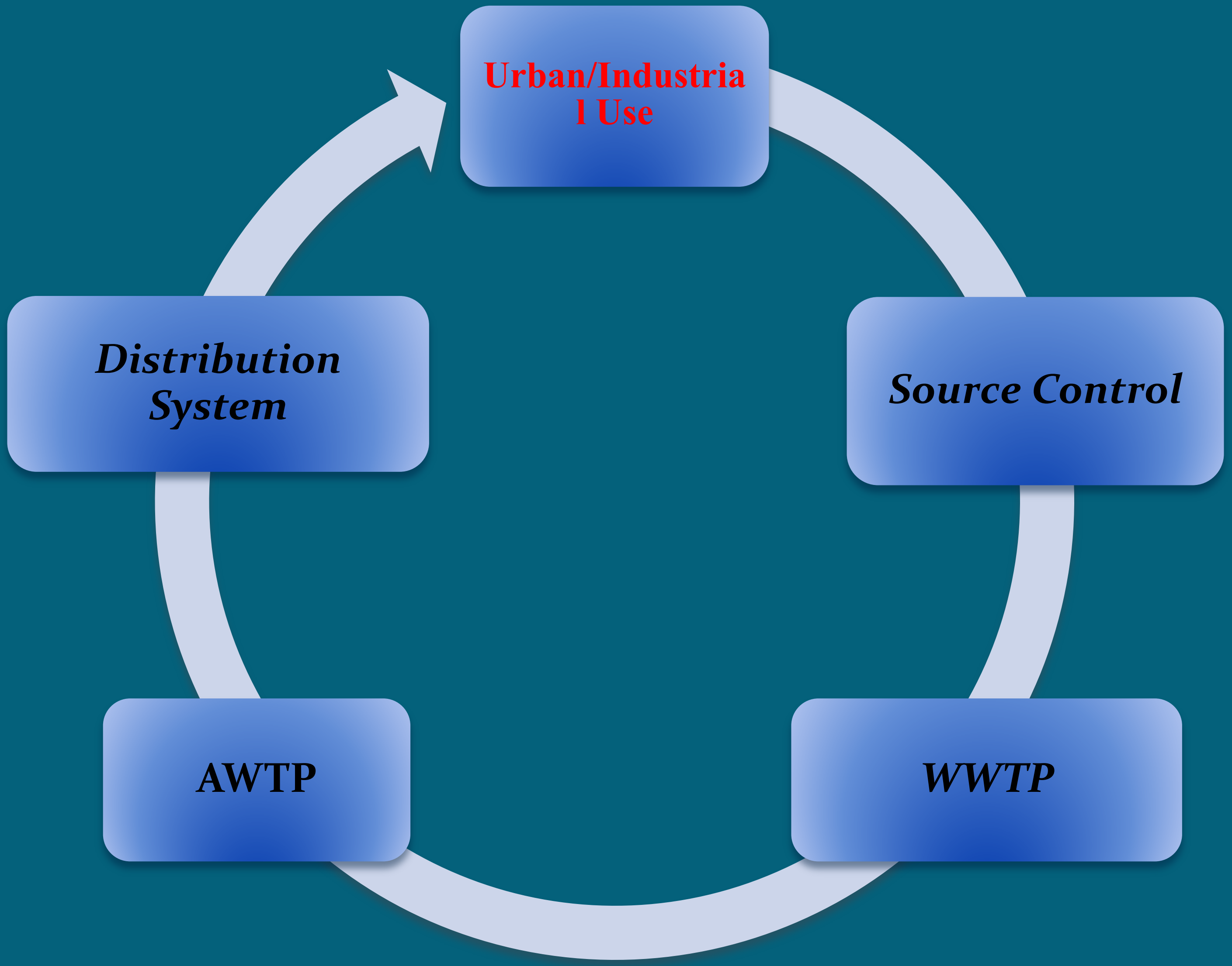
The 'Key Principles' of the 2008 AGWR

- Protection of public health remains paramount;
- Community engagement and support is essential;
- Institutional capacity must be in place;
- Effective trade waste programs must be in place;
- Robust and reliable multiple barriers must be installed;
- *Performance of each barrier must be 'validated'* and then *'verified'* on an on-going basis;
- Personnel skills, training and accountability essential;
- Regulatory surveillance and auditing of entire system.



→ *Seamless communication between Trade Waste Officers and operators of WWTP and AWTP of paramount importance – single point of control*

The Water (Re-)Cycle Barriers



Microbial Health Based Targets

- Risk Defined in terms of *Disability Adjusted Life Year* (DALY's), based on approach by WHO;
- *Tolerable risk* for reclaimed water is a DALY of 10^{-6} per person per year – approx 1 illness (diarrhoea) per 1,000 people;
- Default 95th percentiles for reference pathogens in raw sewage given – *Cryptosporidium* for protozoa & helminths, *Rotavirus/Adenovirus* combination for enteric viruses & *Camphylobacter* for bacteria;
- Based on consumption of 2L/person/day, minimum log reductions from raw wastewaters through the WWTP and AWTP for potable reuse are:
    - 8 Log reduction for protozoa (Cryptosporidium)
    - 8.1 Log reduction for bacteria (*Camphylobacter*)
    - 9.5 Log reduction for viruses (Adeno- and Rotavirus)

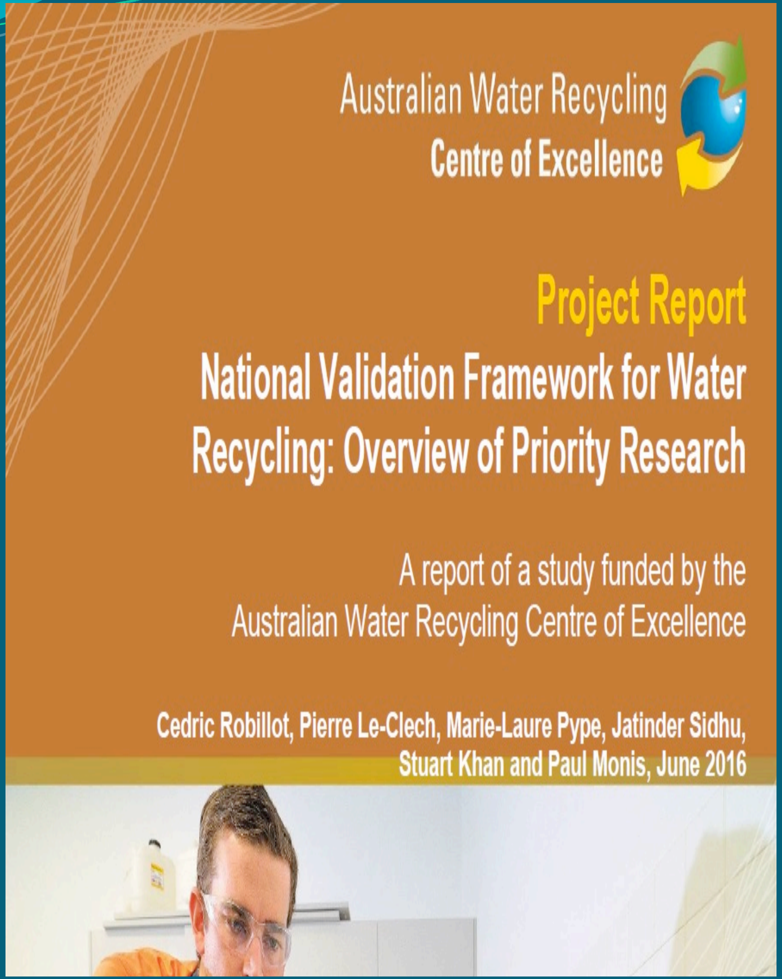
Caveats on Treatment Efficacy

- Treatment processes must be *validated* to demonstrate that they provide the claimed pathogen reductions (published data, pilot plants, challenge testing …);
- Maximum log removal credit per unit process for reference pathogens not greater than 4 in Australia (6 in the US) – *multiple barriers* required;
- Log Removal reductions can only be claimed if they can be *operationally monitored*;
- Implications for membrane systems – MF, UF, NF & RO.

What is ‘Treatment Validation’ ?

Demonstrating the capability of treatment processes to remove or inactivate target pathogens and correlating performance with operational monitoring

National Validation Protocols



Work initiated by the *Australian Water Recycling Centre of Excellence (AWRCE)* and led to the development of *National Validation Protocols* in 2016 for the validation of :

- **Membrane Bioreactors (MBRs);**
- **Ultraviolet Disinfection;**
- **Reverse Osmosis (RO);**
- **Chlorination;**
- **Activated Sludge process.**

The protocols are accepted across all jurisdictions within Australia and that for MBRs is finding application in the US.

https://www.waterra.com.au/research/waterval/

Extract from RO Validation Protocol

Table 1 Potential suitability of surrogates and monitoring methods as a function of LRVs being validated.

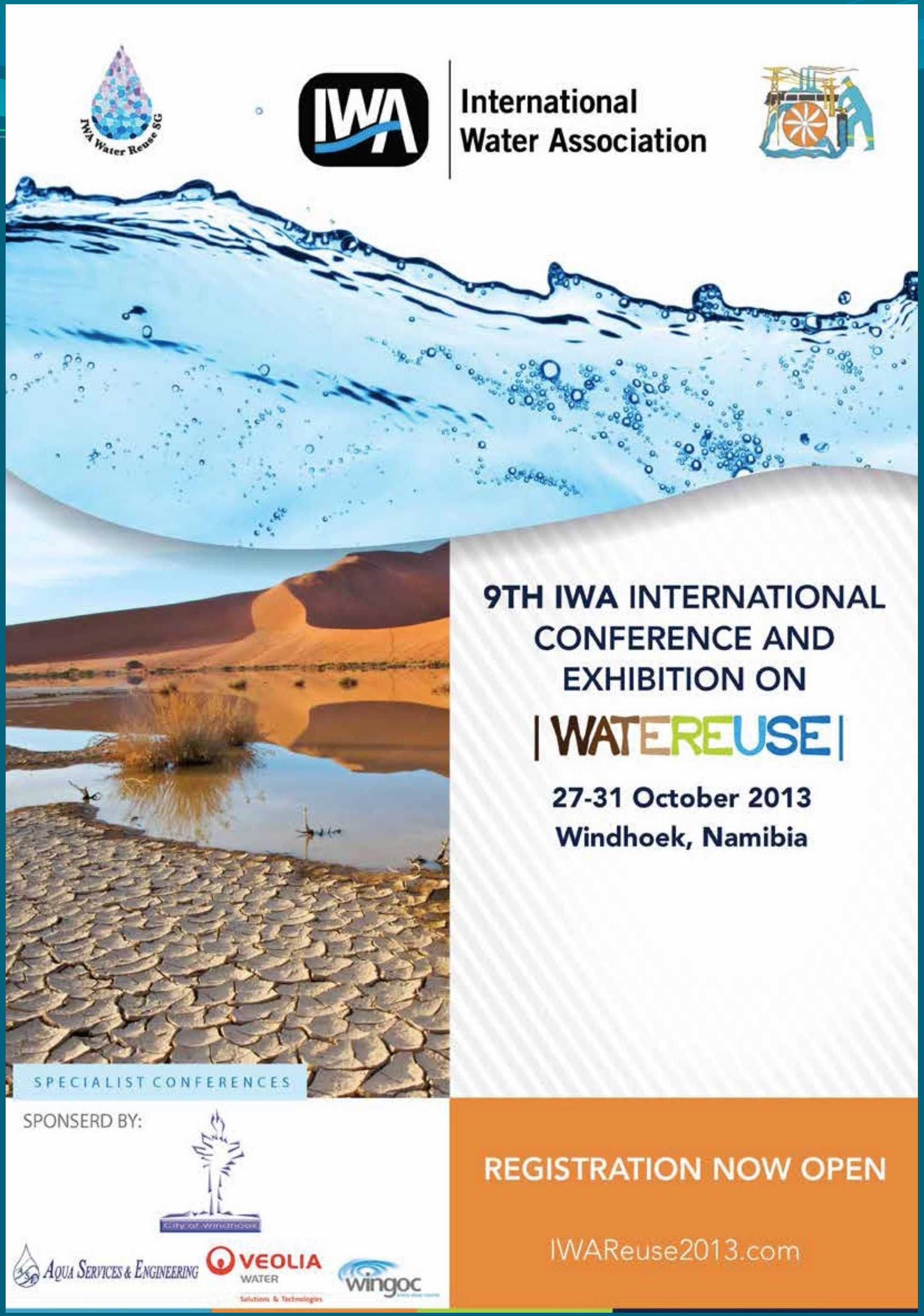
Surrogate	Monitoring method	LRV			
		1	2	3	4
Electrical conductivity	Feed and permeate online monitoring - Spiking option if feed limited	✓	✓		
Total organic carbon	Feed and permeate online monitoring - No spiking[1]	✓	✓		
Dissolved organic matter	Feed and permeate daily grab sampling and analysis - No spiking	✓	✓		
Sulphate	Feed and permeate daily grab sampling and analysis - Spiking option if feed limited	✓	✓	✓	
Fluorescent dye	Feed and permeate online monitoring of spiked[1] fluorescent dye	✓	✓	✓	✓
Fluorescent dye	Feed and permeate daily grab sampling and analysis of spiked[1] fluorescent dye	✓	✓	✓	✓

[1] Spiking can be implemented as discrete pulses or as continuous addition

Validation of the Goreangab Reclamation Plant in Windhoek, Namibia against the 2008 Australian Guidelines for Water Recycling

Ian B. Law, Jurgen Menge and David Cunliffe

Unit Process	Process Design Parameters	*Virus LRV Credit*	*Bacteria LRV Credit*	*Protozoa LRV Credit*
Gammams WWTP	BNR (long SRT)	**0.5-1.0**	**1.0**	**0.5**
Pre O_3 and Coag/DAF	Pre-O3 dose: 3 mg/L Contact Time: 3 min Coag Chem's: $FeCl_3$, HCl, polyelectrolyte DAF SLR: 4 $m^3/m^2/hr$	**Included in DMF**	**Included in DMF**	**Included in DMF**
Dual Media Filtration (DMF)	Rate: 6m/hr Anthracite: 0.7m (ES 1.3) Sand: 0.7m (ES 0.7)	**1.5**	**1.5**	**2.0**
Ozone	Dose: 12mg/L mg O_3/mg DOC: 1.1 Contact Time: 24 mins CT: 12-20 mg/L/min	**4.0**	**4.0**	**(>0.6) 1.5-2.0**
BAC	EBCT: 10 min minimum Bed Depth: 1.5m	**Included in GAC**	**Included in GAC**	**Included in GAC**



Once Validated ..then need on-going *Operational Monitoring* to show no deviations

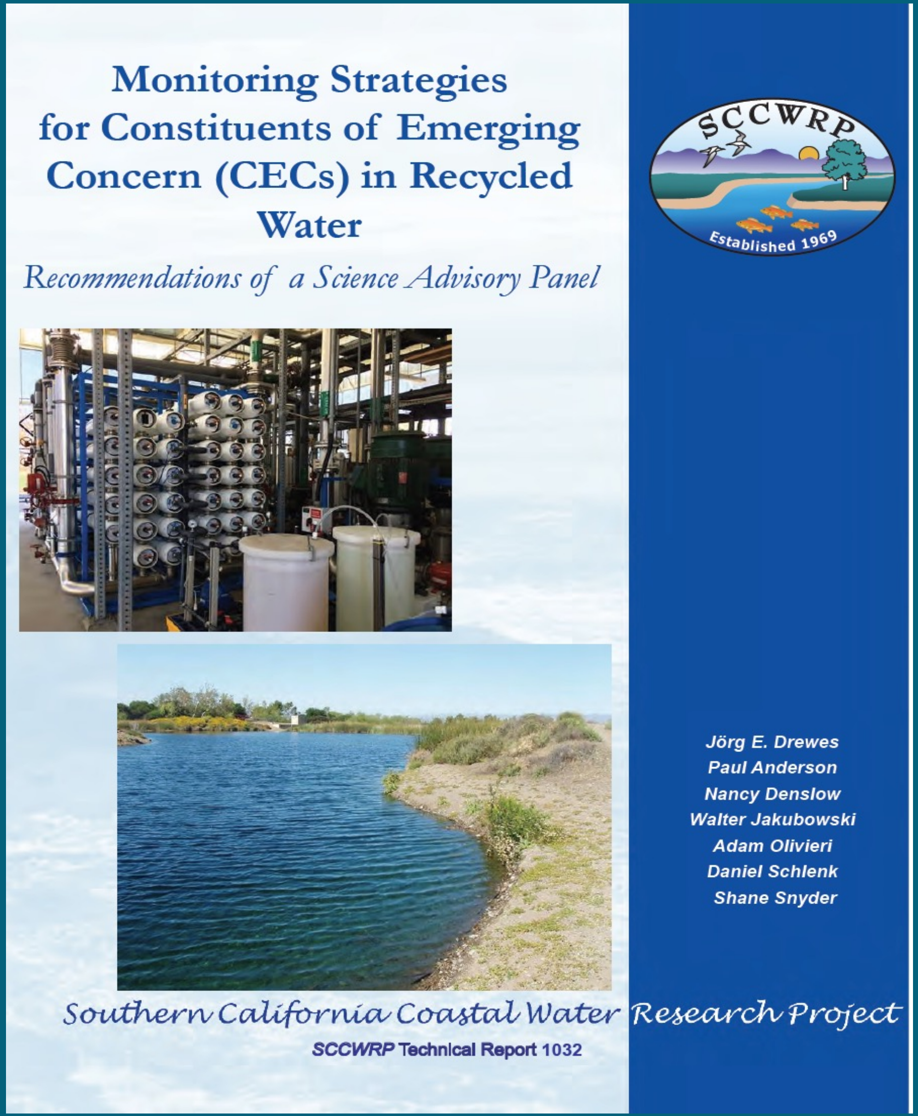
Barrier	On-Line Operational Monitoring*	Laboratory Monitoring	Contingency
1 – Source Control in Collection System	• pH • VOC analysers at nodal points & at WWTP • *Microbial Fuel Cells* • *Real-time sensors (pH, Temp, ORP, Conduct'y, Turbidity) in collection system*	• Regular monitoring of individual trade waste discharges – compliance monitoring • WWTP influent	• Communication/Liaison Plan - media • Trade Waste Regulations • Trade Waste Agreements
2 – WWTP, including MBR, Effluent	• TOC • pH, Temperature • Turbidity • Conductivity • Ammonia	• Routine operational monitoring tests, e.g. MLSS, MLVSS, SRT, effluent SS & DOC • EEM Fluoresence	• All excursions communicated to Source Control & Collection System Managers as well as downstream AWTP operators • Divert effluent away from AWTP?
RO Based AWTP:			
3 – MF/UF	• Filtrate Turbidity • Filtrate Particle Count • Filtrate pH & Combined Chlorine Weekly Membrane Integrity Test (MIT, PDT, PHT)	• On-line instrument verification • EEM Fluoresence	• Feedback to WWTP • Redundant process units • AWTP shutdown – last resort
4 - RO	• Combined/Free Chlorine • Feed ORP/UVT • Permeate Conductivity • Permeate TOC (ppb) • Permeate pH & Flow • Brine Flow & Conductivity	• On-line instrument verification • EEM Fluoresence • Selected RW parameters – SAMP compliance	• Feedback to WWTP • Redundant process units on-line • AWTP shutdown
5 – UV & UV/AOP	• H_2O_2 and/or NaOCl dose (AOP only)	• SAMP Compliance • EEM Fluoresence	• AWTP shutdown – last resort.

5 – UV & UV/AOP	• H_2O_2 and/or NaOCl dose (AOP only) • UV dose • UV transmissivity	• SAMP compliance • EEM Fluoresence	• AWTP shutdown – last resort.
6 – Stab'n & Cl_2	• Free Cl_2 CT • pH • Temperature	• SAMP Compliance • ATP ? • Bioassays	
O_3/BAC AWTP:			
Dual Media Filter	• Turbidity • Particle Count	• Turbidity	
Ozone	• Ozone residual • Ozone CT • Temperature	• Ozone dose (gO_3/gDOC) • EEM Fluoresence	
BAC/GAC	• Turbidity • TOC/DOC	• AOC residual • EEM Fluoresence • ATP	
Water End-Point:			
7– Natural Environment		• Biota Diversity/Health • Chlorophyl a • DO Profile • TOC/DOC	• Stop PRW inflow – last resort
8 - WTP	• pH • Turbidity • Chlorine residual	• Compliance with DWG	• PAC ?

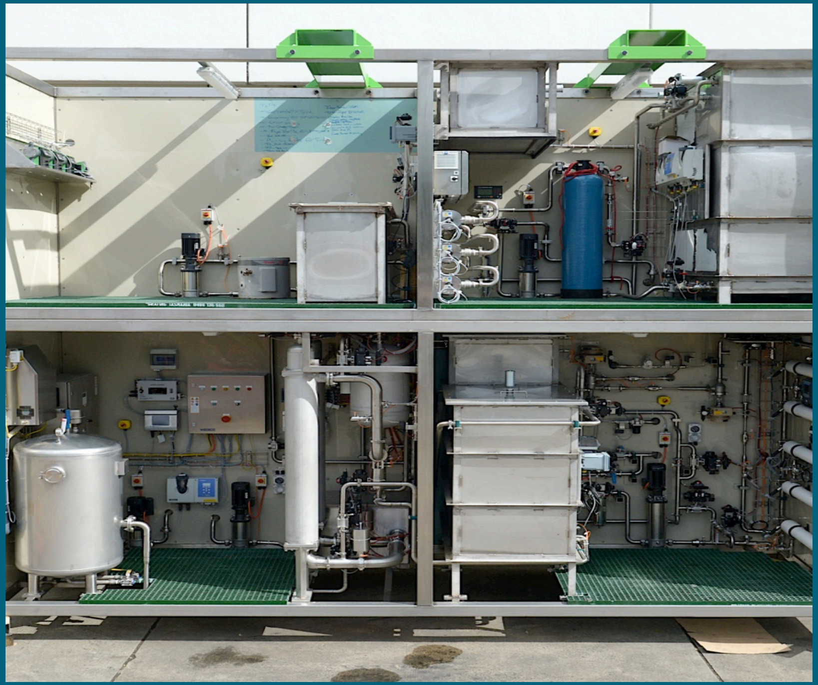
* Denotes instrumentation over and above those required for the operation of the each Barrier and which are an integral part of each unit process that constitutes each of the barriers *with those in Red often being **CCPs***.

Verification Monitoring

- Verifying compliance of reclaimed water quality with relevant quality standards;
- Sampling and Monitoring Program (SAMP) – chemical and microbiological tests; living document, extensive and surrogates
- Bioanalytical tests to verify ‘safety’ of the water - *ER-a* and *AhR* bioassay data should be collected on the product water in PR applications on a quarterly basis.



Linking CEC Removal to Pathogen LRVs – another benefit



Study Outputs:

- Classified molecules based on Class (Aromatic, Aliphatic, Inorganic), Sub-class (EDG, EWG and combinations), Sub-class 2 (Hydrophobic, Hydrophilic, Charged or Neutral);
- *Linked removals to operational CCPs for pathogen removal* and established CoC LRVs for the range of molecules.

For example:

Ibuprofen (aromatic, hydrophilic, EDG, charged) removal through MBR, Ozone & RO: *overall LRV is 2; Triclosan (*Aromatic, EWG, hydrophobic, charged): *overall LRV is 1.8.*

1. Reference: *Scales, P.J. et al (2015). Risk Assessment of the Removal of Chemicals of Concern in the Davis Station AWTP, Project No 3170, Australian Water Recycling Centre of Excellence, ISBN 978-1-922202-55-0, July*

Paper to be presented at AWA Ozwater'22 Conference in May 2022

A NOVEL ADAPTATION OF WATERVAL PROTOCOLS TO ADDRESS CHEMICAL RISKS IN WATER RECYCLING

Hongjiao Pang[1], Mayumi Allinson[1], Aaron Schultz[2], Caitlin Cooper[2], Kathy Anne Northcott[2], Peter J. Scales[1]
1. Department of Chemical Engineering, University of Melbourne, Melbourne, VIC, Australia
2. Veolia ANZ, Melbourne, Vic, Australia

Water Corporation's 18 Surrogates

Surrogates selected as indicators of UF/RO treatment performance

Table 7: RWQI for groundwater replenishment in the Beenyup wastewater catchment

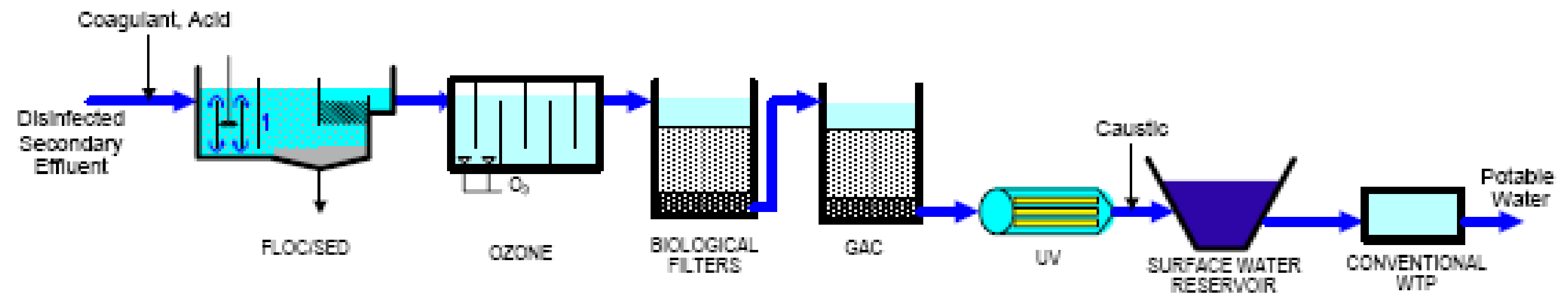
RWQI	Unit	Guideline Value(1)	Limit of reporting	Chemical Group that they represent
Boron	mg/L	4	0.02	Inorganic chemicals
N-nitrosodimethylamine (NDMA)	ng/L	100	1	Nitrosamines
Nitrate as nitrogen	mg/L	11	0.01	Inorganic chemicals
Chlorate	mg/L	0.7	0.01	Inorganic disinfection by-products
1,4-Dioxane	ug/L	50	0.1	Organic chemicals
Chloroform	ug/L	200	0.05	Other disinfection by-products
Fluorene	ug/L	140	0.1	Organic chemicals
1,4-dichlorobenzene	ug/L	40	0.05	Organic chemicals
2,4,6-trichlorophenol	ug/L	20	1	Phenols
Carbamazepine	ug/L	100	0.05	Pharmaceuticals and personal care products
Estrone	ng/L	30	1	Hormones
EDTA	ug/L	250	10	Organic chemicals
Trifluralin	ng/L	50000	1	Pesticides and herbicides
Diclofenac	ug/L	1.8	0.05	Pharmaceuticals and personal care products
Octadioxin	pg/L	9000	2	Organic chemicals
MS2 Coliphage	pfu/L	<1	0.6	Microorganisms / Pathogens
Alpha particle activity	mBq/L	500	10	Radioactive compounds
Beta particle activity (-K40)	mBq/L	500	10	Radioactive compounds

(1) Sampled results should be equal to or less than the guideline value.

The Sustainability Topic

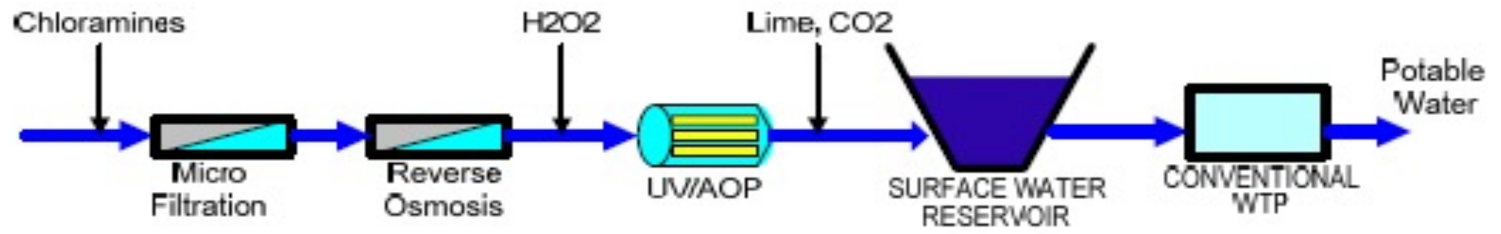
Common Treatment Trains

Figure 1: IPR Treatment Train #1



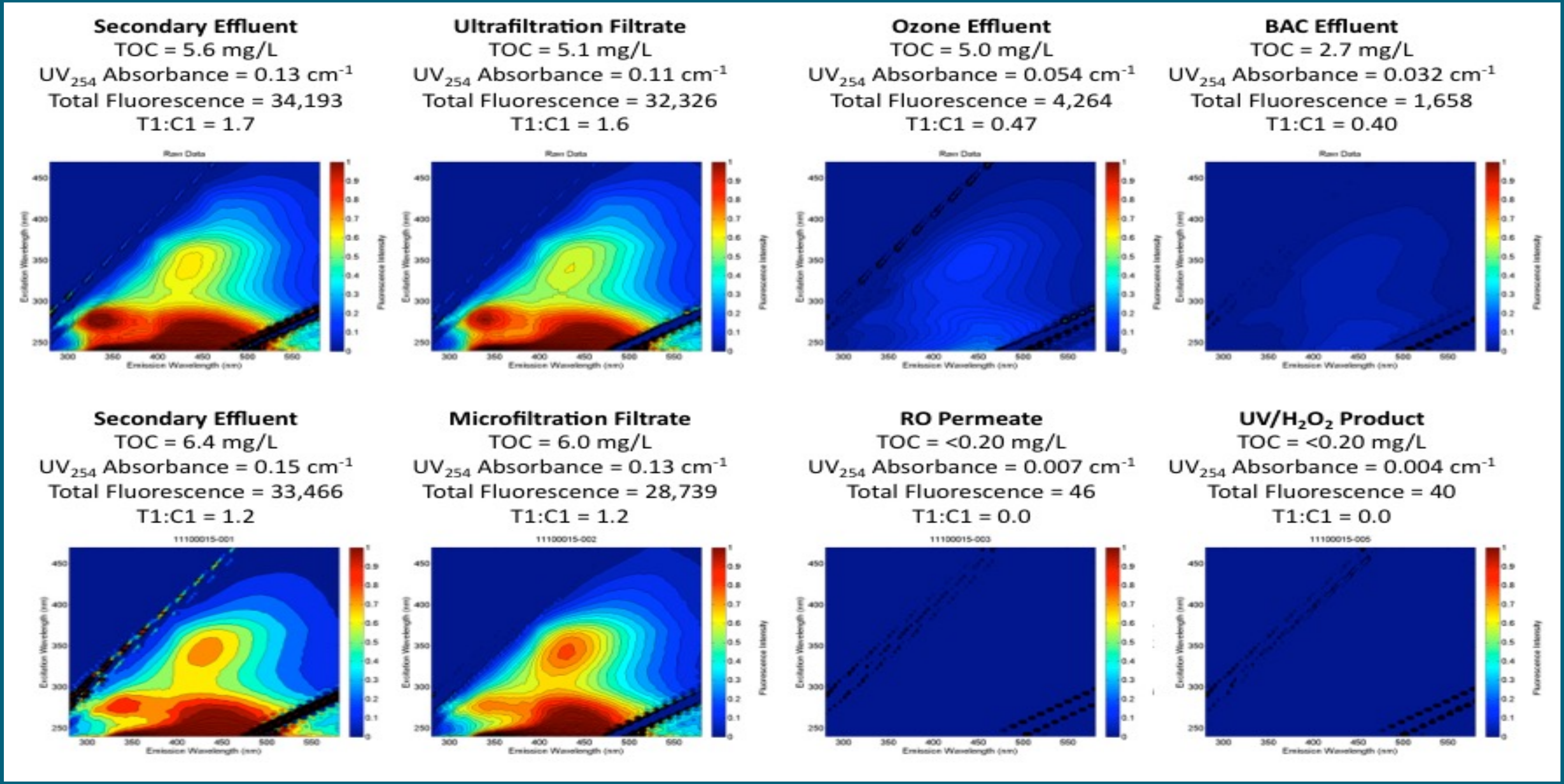
and

Figure 2: IPR Treatment Train #2

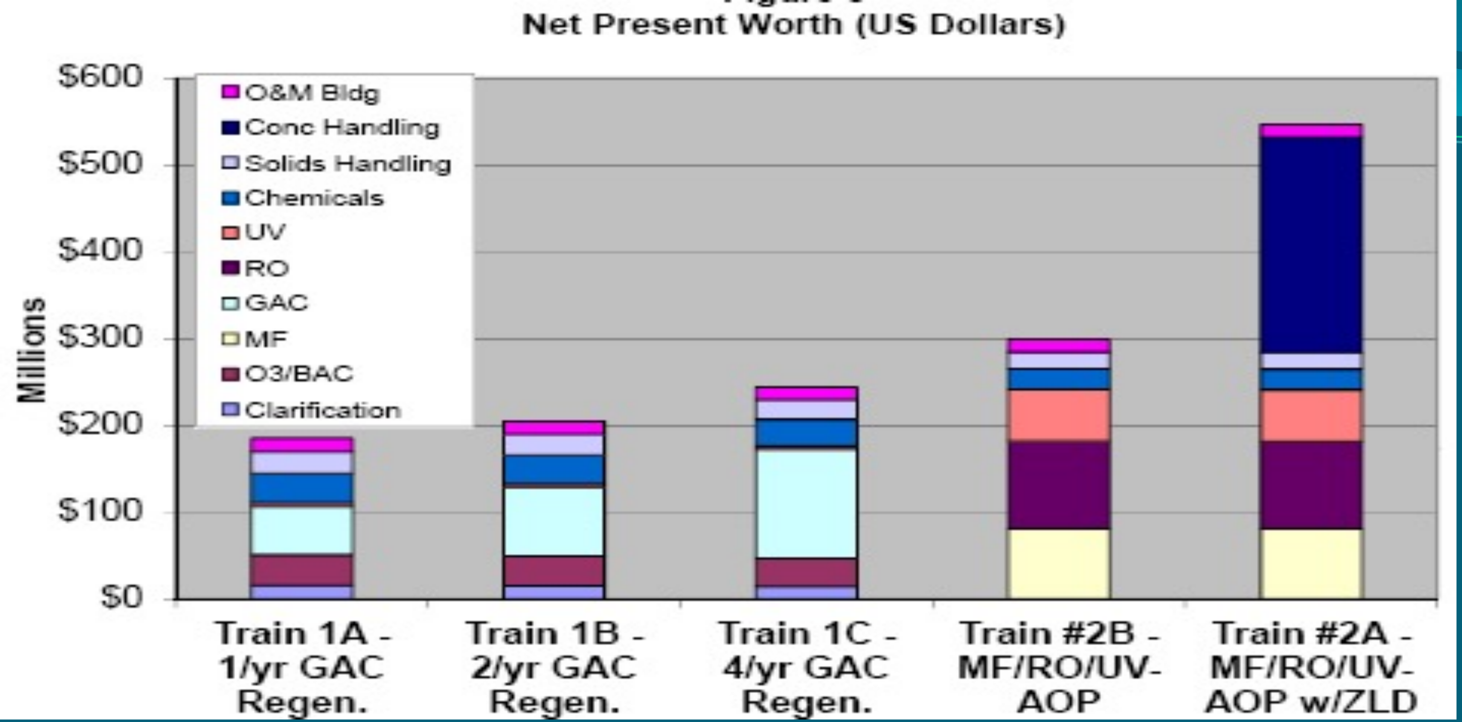


Ref: Schimmoller et al, 2008

UV254 & Fluorescence

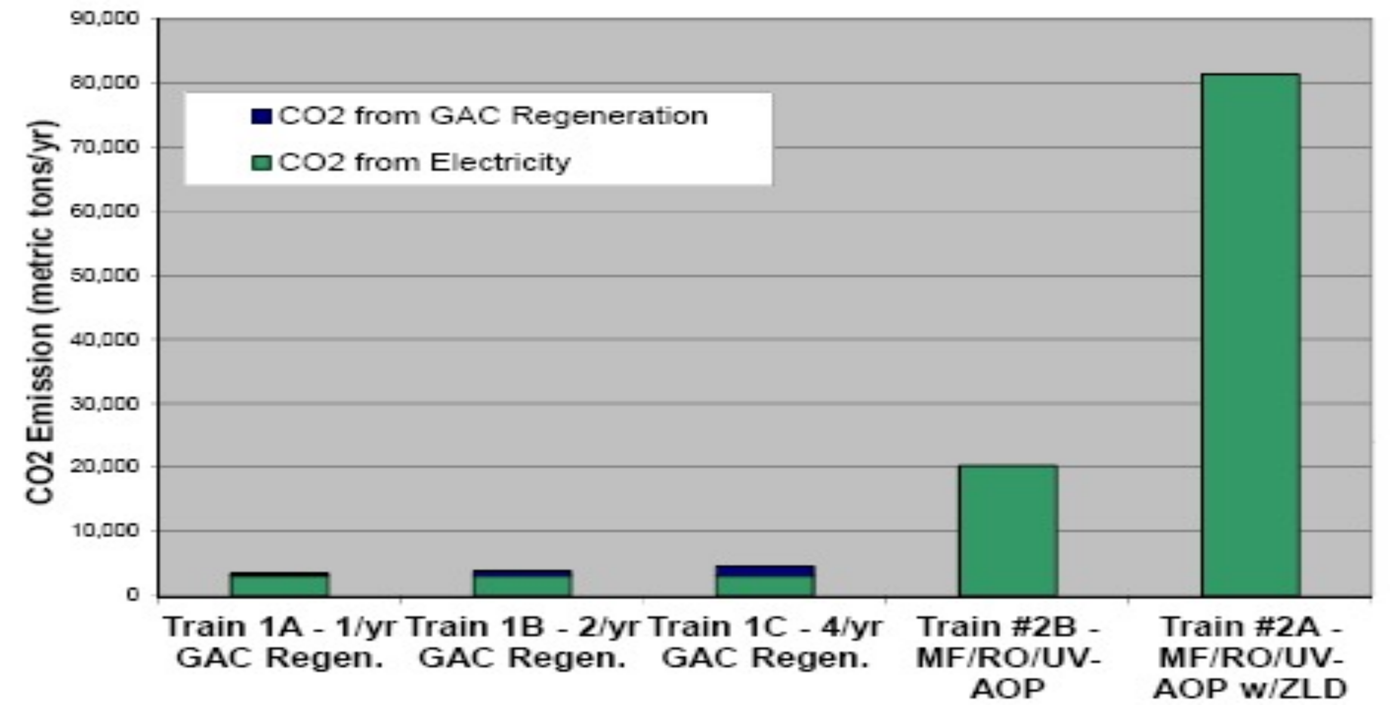


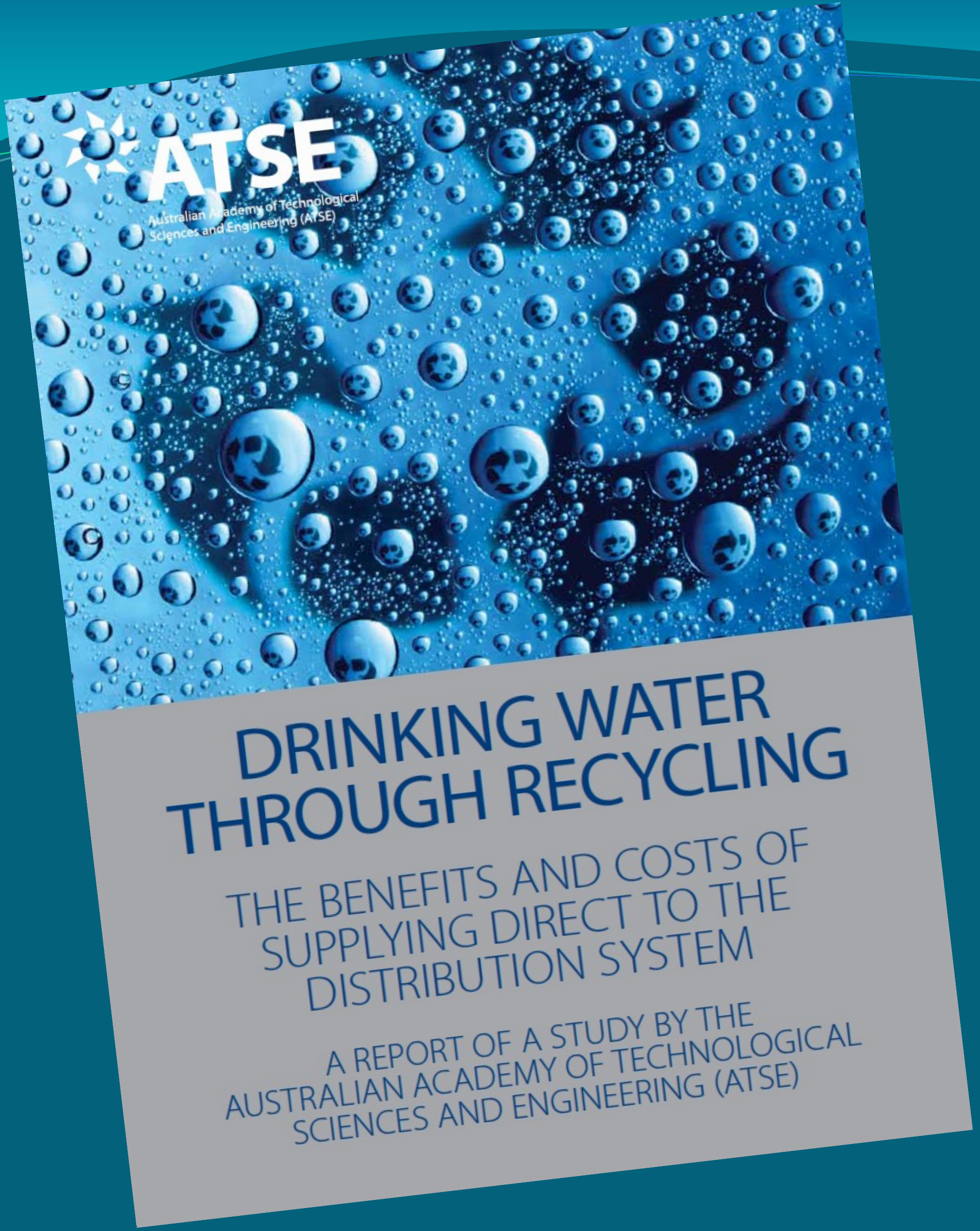
WRRF 11-02, 2013: Equivalency of Advanced Treatment Trains for Potable Reuse



Source: Schimmoller et al, 2008 and updated in 2015

Sustainability – a key consideration when selecting treatment trains for the future.





Report funded by the *Australian Water Recycling Centre of Excellence* (AWRCE) and released in October 2013

Extols benefits of the DPR option – and motivates for its consideration in any assessment of future water supply options.

Communicating with the Public & Politicians on Potable Reuse

We do have some hurdles to overcome – particularly in the political arena

We now know how to engage communities

WATER SERVICES ASSOCIATION OF AUSTRALIA

Lessons from the journeys of others

1

It can be done

Communities around the world have implemented purified recycled water schemes for decades. It could be successfully implemented in Australia, if circumstances warrant.

> The three 'T's:
> Trust • Transparency • Time

2

Trust is critical for securing support for purified recycled water

Transparency and open information sharing will help to develop and maintain this trust.

3

Establishing purified recycled water is complex and takes time

It takes time – up to a decade. People need to be taken on a journey to be comfortable with it. Rushing or imposing deadlines increases the risk of rejection or backlash.

4

Seeing is believing

Investing in a demonstration plant, visitor centre and tour program for 'place based learning' will greatly improve community understanding and support. It can showcase and prove the reliability of the technology, and pre-empt stigma reactions through calm, engaging learning environments.

The experience should be carefully crafted with sequenced messaging to build overall awareness and understanding, and may include sampling the water.

5

Wording and imagery are critical

This will be somewhat specific for each community, so local research is important. Choose words and branding that resonate and do not alienate. Technical jargon confuses people and doesn't build trust.

6

News media coverage has a profound impact on public acceptance

It can make or break a scheme. Proactively engaging key influencers and the media, leveraging social media, and using expert testimony and third party advocacy can help build trust and transparency.

7

Political support is essential

Political cycles can polarise an issue, and force people to take a side. Good engagement across the full political spectrum, to gain and keep support, is critical.

8

Grass roots education and engagement

Can be more effective than high profile marketing activity or 'above the line' presence.

> 'Water should be judged by its quality and not its history'
> LUCAS VAN VUUREN, SOUTH AFRICA

9

General education around the urban water cycle and context

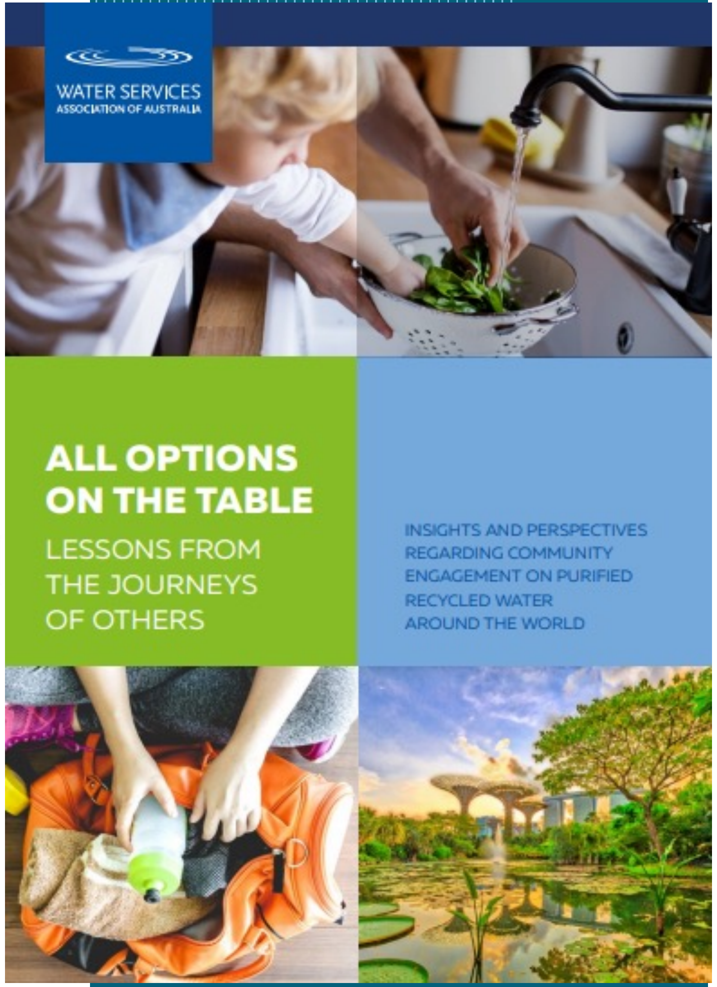
Will help prevent stigma and encourage acceptance. Provide information on the range of long-term supply options, climate trends and cost.

10

Regulators play a powerful role

They will lead government and community perception, and have the authority to determine whether purified recycled water can proceed. It is their role to take a conservative approach to risk management, so it may take a long time for them to become comfortable and produce a regulatory framework. Good regulatory engagement, and high

October 2019



Demonstration plants: where technology, safety and engagement occur side by side

City/town/community that built a demonstration plant/visitor centre	Has the city/town implemented purified recycled water for drinking?
1. Perth, Western Australia – Demonstration plant at Beenyup (the Groundwater Replenishment Trial) and visitor centre	Implemented
2. Singapore – Demonstration plant + NEWater Visitor Centre	Implemented
3. San Diego, California USA - Demonstration plant + Visitor Centre	Implementing
4. Hampton Roads, Virginia USA - SWIFT Research Centre	Implementing
5. Monterey, California USA - Demonstration plant	Implemented
6. Windhoek, Namibia - No formal Demonstration plant but used the designs of the Stander demo Plant in Pretoria in creating the plant in 1968	Implemented
7. Scottsdale, Arizona USA - Decades of indirect potable reuse, now City of Scottsdale Water Campus is effectively a Demonstration plant (gained direct potable reuse permit 2018)	Implemented
8. El Paso, Texas USA - 1 year trial with tours of Fred Hervey plant, now building a new visitor centre	Implemented
9. Water Replenishment District of Southern California, USA - Demonstration plant	Implemented
10. Los Angeles, California USA - 2 demonstration plants, Hyperion Environmental Learning Centre in LA and Glendale.	Already have an operating IPR system at Terminal Island, and there is full intention (already publicly committed) to go near 100% water reuse, mostly from purified recycled water for drinking, by 2035
11. Cape Town, South Africa - Using the temporary plant commissioned during Day Zero, as the demonstration plant.	Due to implement purified recycled water. Full scale Faure plant in design.
12. Gwinnett County, Georgia USA - Gwinnett Environmental and Heritage Center (not focussed on demonstrating purified recycled water)	Implemented
13. Loudoun County, Virginia USA – visitor centre	Implemented
14. Padre Dam, California USA – Demonstration plant + visitor centre with tours	Implementing
15. Luggage Point, South East Queensland Australia (Western Corridor scheme) – small visitor experience	Implemented but as a drought option
16. Soquel Creek, California USA - Did a mock demo, a trailer with equipment and educational materials including Global Connections Map, but no operating system.	Implementing, and the mobile trailer was a key part of winning public acceptance after a long struggle.
17. Orange County Water District, California USA - Created Water Factory 21 in 1975 and used it to demonstrate the effectiveness of the technology to stakeholders from all over the globe (they are considered the textbook case for community engagement), before replacing it in 2008 with their current Groundwater Replenishment System	Implemented
18. Ventura, California USA - A visitor experience (re-used San Diego artwork)	Implementing
19. San Jose/Santa Clara, California USA - Silicon Valley Advanced Water Purification Center. Using a non-drinking facility as a demo	Implementing
20. Las Virgenes, California USA – Demonstration plant + visitor centre	Implementing
21. Oxnard, California USA - Education centre	Implemented

Most places that run a demonstration project have gone on to implement purified recycled water for drinking !! (Ref: Law & Francis, SIWW2021)

NEWater, Singapore

One Example of the Demonstration Plant impact

Demonstration Plant, May 2000

Visitor Centre, Feb 2003

Some additional reading ….

Water Services Association of Australia (WSAA) - PRW toolkit, 2022https://www.wsaa.asn.au/all-options-table-toolkit-purified-recycled-water-drinking

Closure

- The uptake of Purified Water for Drinking (PRW) (aka Potable Reuse) will continue to increase in many countries of the world as the search for reliable climate resilient water supplies intensifies;
- We must continue to investigate and develop technologies that produce a safe purified recycled water with reduced environmental footprint and at affordable cost – *we'll hear about two such technologies in this session*;
- Co-operation/communication between water practitioners around the world is of paramount importance as we move forward in this important initiative.

I wish you all good health and stay safe !!

Thank You !

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