An Australian perspective on DPR: technologies, sustainability and community acceptance

Ian B. Law

ABSTRACT

Australia has had guidelines in place for water recycling (for all uses other than potable reuse) since 2006. These guidelines were extended in May 2008 to cover potable reuse and have since been applied to two potable reuse schemes – one in Brisbane (Queensland) in 2011 and the second in Perth (Western Australia) in 2013. These guidelines cover both indirect potable reuse and direct potable reuse (DPR) and outline the steps that must be followed in the planning and validation of such schemes. This paper summarizes: (i) recent work carried out in Australia on treatment trains and technologies suitable for DPR; (ii) sustainability considerations of DPR and how it compares with other water supply options; and (iii) developments in community education and engagement in the potable reuse space.

Key words | community acceptance, DPR, sustainability, technologies

Ian B. Law
IBL Solutions,
PO Box 226,
Wellington,
New South Wales 2082,
Australia
and
University of Queensland,
Brisbane,
Queensland 4072,
Australia
E-mail: *iblaw@bigpond.com*

INTRODUCTION

Australia has had guidelines for augmenting drinking water supplies in place since May 2008 (National Resource Management Ministerial Council (NRMMC) *et al.* 2008). These guidelines are based on risk identification and management principles and are linked into the Australian Drinking Water Guidelines (Australian Drinking Water Guidelines 2011). They are intended to provide principles and a framework for the safe implementation of water recycling schemes, and underwent both international and national review before being released.

These guidelines focus on a risk management rather than a risk avoidance approach to ensuring the end product water quality, with a reliance on multiple barriers in the treatment train. The guidelines consider both acute and chronic health impacts and there is an acknowledgement that, with the multiple barriers in place, the critical issue is the acute health impact.

Although these guidelines are not mandatory and have no formal legal status, their adoption provides a shared national objective; at the same time, it allows flexibility of response to different circumstances at regional and local levels.

The guidelines discuss both indirect and direct augmentation and at the time of their production (May 2008) there was a strong preference for the indirect alternative, much as was prevalent at that time in the USA and Europe. In large measure this preference was based on the perception that the public would only accept potable reuse if the water was returned to some sort of natural water body. However, there is now increasing recognition that this perception was incorrect and borne of a lack of understanding of the context of water use and reuse and the fact that the direct augmentation option can have significant advantages, as this paper identifies.

In addition, there has been a growing awareness in Australia that a diverse portfolio of water supply options is essential to mitigate the risks associated with population growth and climate change into the future. This, in turn, has resulted in increasing discussion on potable reuse and the merits or otherwise of the two forms: indirect potable reuse (IPR) and direct potable reuse (DPR).

doi: 10.2166/wrd.2015.180

The Australian Academy of Technological Sciences and Engineering (ATSE) published a report in October 2013 entitled *Drinking Water through Recycling: The benefits and costs of supplying direct to the distribution system* (Australian Academy of Technological Sciences & Engineering (ATSE) 2013). This report was funded by the Australian Water Recycling Centre of Excellence (AWRCE) and from it ATSE concluded the following:

- DPR should be considered among the range of available water supply options for Australian towns and cities.
- It is concerned that DPR has been pre-emptively excluded from consideration in some jurisdictions in Australia in the past, and that these decisions should be reviewed.
- Governments, community leaders, water utilities, scientists, engineers and other experts will need to take leadership roles to foster the implementation and acceptance of any DPR proposal in Australia.

This paper summarizes recent work carried out in Australia on treatment trains and technologies suitable for DPR, sustainability considerations of DPR and community education and engagement.

TECHNOLOGY

The technology requirements for the production of a high quality of water for potable reuse applications – be it IPR or DPR – are understood, and the majority of advanced reclamation plants in Australia are membrane-based: microfiltration (MF) or ultrafiltration followed by reverse osmosis (RO) and either advanced oxidation or ultraviolet disinfection (UV). This process train appears to be the default process for many advanced reuse schemes, in Australia and internationally at present.

However, experience is showing that this train, while producing an exceptional product water quality, is not as cost-effective or as sustainable as those trains that do not include RO, such as the Upper Occoquan Service Authority plant in Virginia, USA (operational since 1978) and the Goreangab DPR Plant in Windhoek (operational since 1968). These concerns are generally associated with the high energy usage of the RO process, the management and disposal of the concentrate (particularly for non-coastal applications) and chemical usage to maintain membrane throughput. There is thus increasing interest in treatment trains that either do not involve RO or replace the RO step with technologies such as nanofiltration (to reduce energy use) or improve removal of organic material ahead of the RO to reduce the rate of membrane fouling and thus reduce overall chemical usage.

Non-RO-based treatment trains

Non-RO-based treatment trains generally include an activated carbon adsorption stage (or stages), often in conjunction with ozone. Law *et al.* (2013) reviewed the performance of four plants in Australia (two in Queensland, one in New South Wales and one in Victoria) and the Goreangab Water Reclamation Plant in Windhoek, Namibia in terms of trace organic compound (TrOC) removal and concluded that the non-RO treatment trains that incorporate the ozone and activated carbon processes are effective at removing a wide range of TrOCs down to below detection level, and in the case of those that are detected, to below the Health Guideline Values as outlined in the Australian Guidelines for Recycling (NRMMC *et al.* 2008).

An evaluation of the microbial removal capability of the Goreangab WRP in Windhoek, Namibia (a non-RO-based plant) against the requirements of the Australian Guidelines for Recycling found that, based on the system of validation outlined in the evaluation, the multiple treatment barriers did result in microbial removals that met the default values presented in the guidelines (Law *et al.* 2015). It was concluded that this lends further support to consideration of such non-RO-based plants for advanced reuse applications.

Schimmoller *et al.* (2008) introduced ‘sustainability’ into their assessment of treatment trains and carried out a triple bottom line (TBL) analysis of the MF-RO-UV and ozone-BAC-GAC-UV process trains. They show that the capital and operating costs of the RO-based train can be some 50 and 67% higher than those for the non-RO-based train, while the greenhouse gas (GHG) emissions can be 400% higher, principally due to the higher energy requirements of RO. These data are currently being updated for plant capacities of 20, 80 and 270 ML/d, and confirm that the non-RO-based treatment train can have a 'sustainability' advantage over the RO-based train.

Improving organics removal ahead of the RO to reduce the rate of membrane fouling and thus reduce overall chemical usage

The AWRCE is currently funding a project that is investigating the robustness and operational reliability of a small scale advanced water treatment plant (AWTP) that could be used for DPR at Australia's Davis Station in Antarctica. The feedwater to the AWTP is effluent from a membrane bioreactor, and the AWTP treatment train is: ozonation, ceramic MF, biologically activated carbon, RO, UV, stability correction and chlorination. Figure 1 shows the arrangement of the AWTP.

The aims of this study are:

- to produce a water that complies with the Australian Guidelines for Recycling;
- to produce an RO concentrate of low toxicity (as it will be discharged into a sensitive marine environment);
- to minimize chemical consumption to reduce both environmental impact and remote chemical inventory;
- to confirm that the operation of the AWTP can be controlled remotely and requires only limited 'local' input.

The plant is currently sited at a wastewater treatment plant in Tasmania where its operation and performance is being monitored, and any problems identified and rectified, before it is shipped to Antarctica. Tests to date confirm compliance with the Australian guidelines, and indications are that chemical use is reduced. This latter item will be further evaluated during 2016 and before shipping, as will the operational reliability of the plant.

Figure 1 | Layout of the Davis AWTP.

SUSTAINABILITY

The term 'sustainability' is commonly used in the water industry, but its meaning and just how it is measured are not clear to many. The term originated in the accounting industry in the mid-1990s, when a new framework that included not only company profit but also social and environmental components was developed and became known as the TBL. TBL 'captures the essence of sustainability by measuring the impact of an organisation's activities on the world … including both its profitability and shareholder values and its social, human and environmental capital' (Savitz 2006).

The Water Services Association of Australia (WSAA) developed a 'Sustainability Framework of Urban Water Systems' in February 2008 that is now commonly used by water utilities in Australia (Water Services Association of Australia (WSAA) 2008). The framework outlines six phases by which a preferred option is identified that meets all stakeholder expectations in terms of 'sustainability'.

Initially, only energy usage was considered as a 'sustainability indicator' as this is associated with greenhouse gas emissions but, more recently, the number of indicators has grown, along with the use of life cycle inventory analysis (LCIA), which aims to account for all the materials and energy used in the system of interest. Factors such as all flows into and out of the system, including raw resources, chemicals and other materials, energy by type, water and emissions to air, water and land are considered. The identification of the sustainability indicators is a key action that must be addressed at the outset of any TBL analysis.

A report released in Australia in 2007 developed a hypothetical case study for a coastal city that requires an additional 100 ML/d of water to meet its water supply shortfall (GHD 2007). This shortfall could be met by seawater desalination or IPR, and a cost analysis together with energy usage estimates was carried out. The results showed that IPR and seawater desalination had similar total costs when the 'transport' costs are included along with the 'treatment' costs.

DPR, which was not addressed in the report, is expected to have virtually the same treatment cost as IPR but without the significant transport and pumping costs associated with the IPR option (due to the fact that, for IPR, the storage is generally a distance away from the coast while the wastewater treatment plants are located near the coast). On this basis, and using the data in the report, DPR may be more cost-effective than both desalination and IPR (by 40–50%), and it also has the lower energy usage of the two – as is shown in Table 1 (Law 2008). The DPR option will also maximize the use of existing infrastructure.

A more recent and directly relevant report entitled *Financial and Life Cycle Inventory Analysis of Alternative Water Supply and Recycling Options in Australia* was published in October 2013 as an appendix to the ATSE report (GHD 2013; Australian Academy of Technological Sciences & Engineering (ATSE) 2013).

This latter report considered four options for a hypothetical large coastal city – seawater desalination, IPR, DPR and a dual supply system (third pipe system) – to produce some 120 ML/d or 40GL/annum of water. The report compared capital and operating costs and LCIA associated with the construction and operating phases of each option. It excluded wider life cycle impact potentials (e.g., ecotoxicity, ozone depletion, human toxicity, etc.) as well as wider economic benefits or costs to society, while GHG emissions were limited to only those directly associated with the plants – i.e., there was no inclusion of corporate operations etc. Indicative project capital cost and breakdown for each option are shown in Figure 2, while Figure 3 shows the GHG production estimates.

Table 1 | Comparison of water supply options (GHD 2007; Law 2008)

Supply option	Transport distance (km)	Cost of water (AUD$/ML)	Energy usage (kWh/kL)
IPR	100	1,300	1.9
Seawater desalination	20	1,400	4.3
DPR	20	800	1.5

An observation drawn from this report (refer to Figure 2) is that, in terms of net present value (NPV), seawater desalination and IPR are the highest cost options, while DPR and dual pipe recycled water systems are lower. However, in

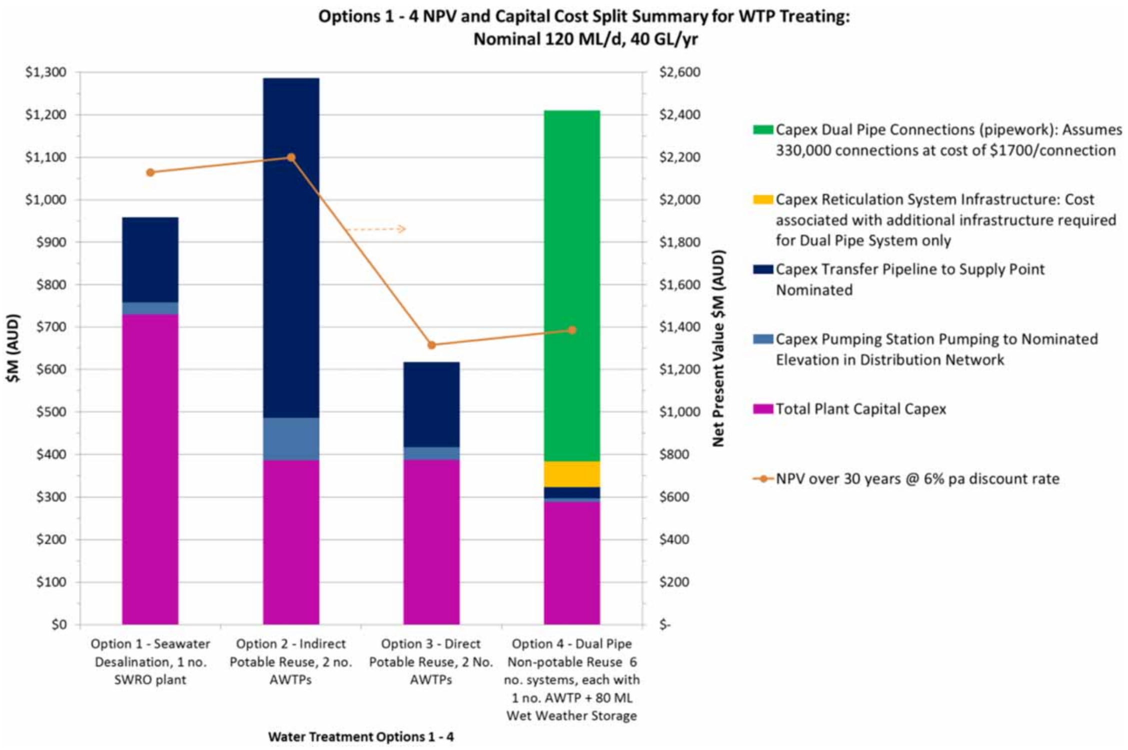

Figure 2 | Indicative project capital cost breakdown and NPV for the four options. The full colour version of this figure is available in the online version of this paper: http://dx.doi.org/10.2166/wrd.2015.180.

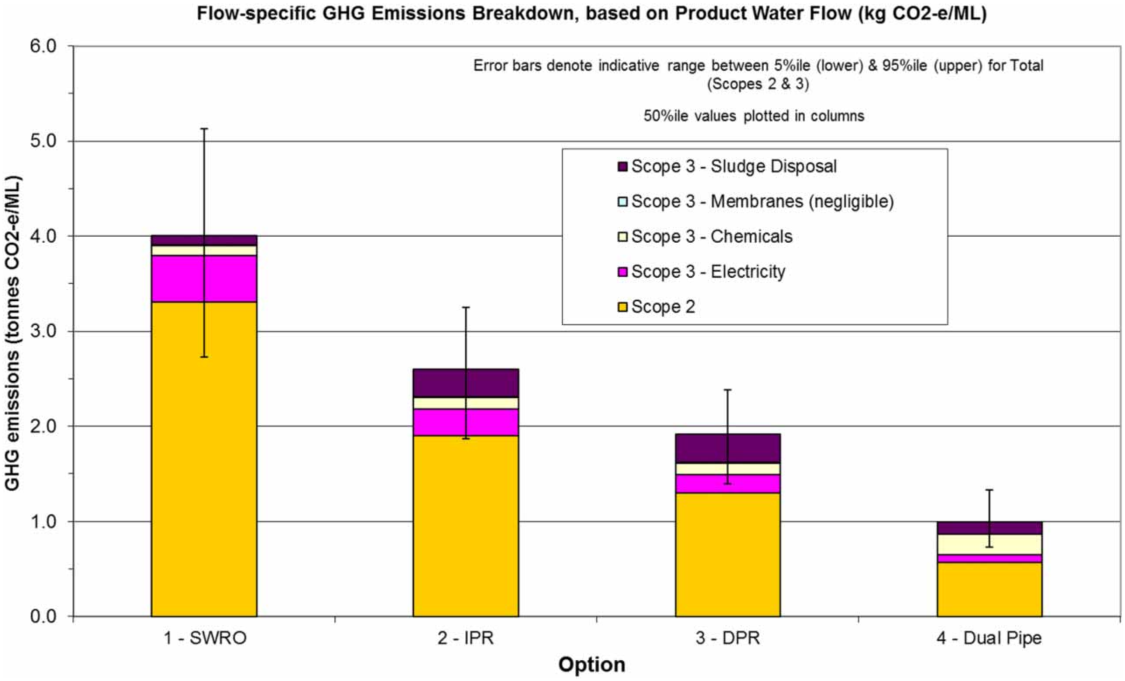

Figure 3 | Greenhouse gas estimates for operational phase (at design flow) of the four options considered (Scope 2, emissions from purchased electricity; Scope 3, emissions from all other sources).

capital cost terms, IPR and dual pipe systems could potentially carry the highest cost, followed by desalination, with DPR being potentially the lowest capital cost option, subject to lengths of transfer pipelines and product delivery system requirements (including head).

It is concluded from the above that DPR should be considered in any options analysis for a future water supply, and particularly for coastal cities.

A WateReuse Research Foundation research project, entitled *Methodology for a Comprehensive Analysis (TBL) of Alternative Water Supply Projects Compared to DPR* is currently underway, with the University of New South Wales (UNSW) as one of the research partners. The project is due to be completed by December 2016. The author's company is part of the project team, and a number of Australian and US water utilities are stakeholders in the project (Stanford *et al.* 2014).

COMMUNITY ENGAGEMENT AND ACCEPTANCE

The AWRCE commenced operation in 2010. One of its goals was to fund a project that had the overall aim of 'overcoming the barriers to reclaimed water being viewed as an acceptable 'alternative water' for augmenting drinking water supplies'. This project, known as the National Demonstration, Education and Engagement Program (NDEEP), has recently been completed (Australian Water Recycling Centre of Excellence (AWRCE) 2014).

This project has developed a suite of high quality, research-based education tools and engagement strategies that can be used by the water industry when considering water recycling for drinking purposes. The products are fully integrated and can be used at different phases of project development commencing at 'just thinking about water recycling for drinking water purposes as an option' to 'nearly implemented'. These products include:

- reports and videos on the needs, benefits and resilience of the treatment processes;
- reports on risk communication, governance, decision-making and pricing-related impediments to investment in water recycling;
- a *Global Connections Map* showing information featuring expert and citizen commentary on potable reuse schemes internationally including one scheme in Australia (Perth);

- *Water: Think and Drink*, a series of six animations that explore a range of issues around our drinking water future;
- *'The Water Cycle Explorer'*, a 15 minute video that explores the complexity of the water cycle;
- a web-based platform providing a searchable video library for housing the NDEEP products.

An online survey was carried out in October 2014 to evaluate the effectiveness of the *Global Connections Map*, the six *Think and Drink* animations and the *Water Cycle Explorer* video (Johnson 2014). The survey involved 400 respondents in each of Australia's largest cities, Brisbane, Sydney, Melbourne and Perth, and conclusions drawn were as follows:

- Respondents in the four cities were generally supportive of water reuse and are open to learning more about the option.
- A small amount of information (10 minutes of a video) had the effect of raising support for potable reuse from 54 to 78% and reducing opposition from 24 to 10%.
- After seeing the video, trust in water reuse technology increased for 54% of respondents and trust in their utility increased for 49% of respondents.
- After seeing the video, 80% of respondents stated it was either 'likely' or 'very likely' that they would drink water from a potable reuse scheme if there were a serious need to do so.

The survey confirmed that exposure to a small amount of well-crafted education makes people feel more knowledgeable about water issues, can improve understanding of the water cycle and can increase support for potable reuse.

It is of interest to note that these findings corroborate those presented in four earlier research projects, involving researchers from Australia and the USA:

- WRRF-07-03: Talking About Water: Vocabulary and images that support informed decisions about water recycling and desalination (Macpherson & Slovic 2008).
- NWC Waterlines No 49: Talking About Water: Words and images that enhance understanding (Simpson & Stratton 2011).
- WRRF-09-01: Effect of Prior Knowledge of Unplanned Potable Reuse on the acceptance of Planned Potable Reuse (Macpherson & Snyder 2012). This project evaluated the impact of education on the acceptance of IPR and DPR.
- WRRF-12-06: Guidelines for Engineered Storage of Direct Potable Resue Systems, Task 3: The Ways of Water – Communicating about IPR and DPR without the Acronyms (Salveson *et al.* 2014).

The educational products that were created in the AWRCE project are now promoted under the banner of *Water360* and are suitable for use by communities, government, media and industry. They are designed to be flexible and adaptable; they can incorporate local content and context, be combined in various ways, and link to school curricula or existing utility educational materials. They are adaptable to multiple platforms, both new and traditional – from kiosks and long-form documentaries to video walls, interactive screens, social media, and phone and tablet apps.

In 2014, the AWRCE received the WateReuse Association's Water Reuse International Award that recognises *Water360*'s contribution to the advancement of water reuse worldwide. WateReuse entered into a partnership with the AWRCE to adapt and expand the educational products from their research on education and engagement. These products will be applied by US utilities that are WateReuse subscribers.

CONCLUSIONS

Potable reuse has, in recent times, become an accepted option for achieving security of water supply into the future and IPR (as opposed to DPR) has historically been the preferred option. There is now evidence that in some areas, particularly for coastal cities, DPR can be a more 'sustainable' solution.

As the need for sustainable solutions to water supply provision increase, so will the need to get the 'water message' out, and there are now products that can be applied in this area.

ACKNOWLEDGEMENTS

The assistance of David de Haas (GHD Pty Ltd) and Linda Macpherson (New Water ReSources) in the preparation of this paper is gratefully acknowledged.

REFERENCES

Australian Academy of Technological Sciences and Engineering (ATSE) 2013 *Drinking Water through Recycling: The benefits and costs of supplying direct to the distribution system*. www.atse.org.au (accessed 29 October 2013).

Australian Drinking Water Guidelines 2011 National Health and Medical Research Council & National Resource Management Council.

Australian Water Recycling Centre of Excellence (AWRCE) 2014 www.australianwaterrecycling.com.au (accessed 21 November 2014).

GHD 2007 Using recycled water for drinking – an introduction. Occasional paper No. 2, prepared for the National Water Commission.

GHD 2013 *Financial and Life Cycle Inventory Analysis of Alternative Water Supply and Recycling Options in Australia, Appendix B of ATSE Report on Drinking Water through Recycling: the benefits and costs of supplying direct to the distribution system*. www.atse.org.au (accessed 29 October 2013).

Johnson, S. 2014 NDEEP Stream 3 product evaluation report. A report of a study funded by the Australian Water Recycling Centre of Excellence.

Law, I. 2008 The future direction for potable reuse. *Water Journal of the Australian Water Association* **35** (8), 58–63.

Law, I., Menge, J., Reungoat, J. & Mieog, J. 2013 Performance and validation of non-RO based treatment trains for potable reuse. In *Paper presented at IWA Asia Pacific Water Recycling Conference*, Brisbane.

Law, I., Menge, J. & Cunliffe, D. 2015 Validation of the Goreangab reclamation plant in windhoek, Namibia against the 2008 Australian guidelines for water recycling. *Water Reuse and Desalination* **5** (1), 64–71.

Macpherson, L. & Slovic, P. 2008 *Talking about Water: Vocabulary and images that support informed decisions about water recycling and desalination.* WRRF-07-03. WateReuse Foundation, Alexandria, VA.

Macpherson, L. & Snyder, S. 2012 *Effect of Prior Knowledge of Unplanned Potable Reuse on the acceptance of Planned Potable Reuse*. WRRF-09-01. WateReuse Foundation, Alexandria, VA.

Natural Resource Management Ministerial Council (NRMMC), Environment Protection and Heritage Council & National Health and Medical Research Council 2008 Australian Guidelines for Recycling: Managing Health and Environmental Risks (Phase 2): Augmentation of Drinking Water Supplies.

Salveson, A., Steinle-Darling, E., Trussell, S. & Macpherson, L. 2014 *Guidelines for Engineered Storage for Direct Potable Reuse*. WRRF-12-06. WateReuse Foundation, Alexandria, VA.

Savitz, A. 2006 *The Triple Bottom Line*. Jossey-Bass, San Francisco, CA.

Schimmoller, L., Bellamy, B. & Curl, J. 2008 Indirect potable reuse: balancing costs and benefits. In *Paper presented at IWA Reuse Conference*, Barcelona.

Simpson, J. & Stratton, H. 2011 Talking about Water: Words and images that enhance understanding. NWC Waterlines No. 49.

Stanford, B., Johns, G., Khan, S. & Wiedmann, T. 2014 *Development of Methodology for Comprehensive Analysis (Triple Bottom Line) of Alternative Water Supply Projects Compared to Direct Potable Reuse.* WRRF-14-03. WateReuse Foundation, Alexandria, VA.

Water Services Association of Australia (WSAA) 2008 Sustainability Framework: Part A: Methodology for evaluating the overall sustainability of urban water systems. WSAA Occasional paper No. 17.

First received 12 October 2015; accepted in revised form 11 November 2015. Available online 11 December 2015