Water Reuse in Australia: Current Status, Projections and Research

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ABSTRACT: Water reuse from sewage treatment plants in Australia in 1998/99 was 113 GL (ie. 7% of STP effluent). A recent survey of projected reuse shows this will increase by at least 28 GL/yr to double in four years. The adoption of water reuse is much faster than had previously been predicted due to a number of recent drivers for change in water management. Reuse plans for stormwater and irrigation drainage, with some exceptions, are currently sparse. The paper summarises the research needed to facilitate water reuse and ensure that public and environmental health are protected as identified through a survey with respondents from all states and the Northern Territory. A cross-section of currently uncoordinated Australian research is also presented. Major reuse research programs elsewhere in the world are listed and the gaps that need to be addressed in a proposed national reuse research program are presented.

1. INTRODUCTION

In September 1999, the Australian Water Association formed a special interest group, the Water Recycling Forum, to foster improved communication on water recycling and reuse in Australia (Anderson (ed.), 1999).

In Australia, the driest continent, water resources development until the 1990's generally failed to regard water as more than a single-use disposable product, except where hydro-electric power was the first use. With two thirds of the population now inhabiting the five largest cities, Y3K compliance will demand that Australians have a new vision for water resource management (Harris, 2000). In many areas, trends in water consumption are unsustainable and adaptive management of water will be required to sustain economic growth (Thomas *et al.*, 1999). Against this background a series of events in the late 1990's converged to radically accelerate implementation of water recycling.

Firstly, an awareness of environmental flows began to emerge in water resources management policy. The importance of water for ecosystem support has revealed an environmental cost in diverting water from streams for urban consumers. Secondly, the deteriorating state of rivers, coastal and estuarine waters in the vicinity of urban centres has led to imposition of limits on nutrient discharges to these water bodies. The blue-green algal bloom on a 1000km length of the Darling River drew attention to the alternatives to discharging municipal effluent into streams, and instead disposing to land to harvest water and nutrient benefits. Although this has been practiced at Melbourne's Western Treatment Plant at Werribee for more than 100 years, the practice is not universal and does present issues for protection of soil (Bond, 1998) and groundwater (Snow *et al.*, 1998).

Until the 1990's no major Australian city had any more advanced sewage treatment than secondary treatment, and some cities were still piping primary treated effluent into high energy coastlines and relying on dispersion. The detection of sewage debris and high coliform counts at Bondi Beach raised public awareness on the need for improved treatment prior to marine disposal. Subsequently the Federal Government's Clean Seas Program (to improve the quality of waters discharging to the coast) brought opportunities to sell reclaimed water of improved quality as an irrigation resource. In 1999 the largest such project commenced in Australia. This is the Virginia Pipeline Scheme where 22,000 ML of advanced-treated reclaimed water has been contracted from the Bolivar STP near Adelaide to irrigate market gardens on the Northern Adelaide Plains.

The COAG Water Reform Agenda which introduced competition into the Australian water industry, and demanded that water pricing reflect actual costs of managing water supply and sewage systems, has brought with it a wave of new private sector investment in water infrastructure. The involvement of international water companies has facilitated BOO and BOOT schemes and the adoption of a wider range of technologies in wastewater treatment, including dissolved air flotation, microfiltration, activated carbon filtration, reverse osmosis and biological nutrient removal. The combined effect of these factors has resulted in an exponential growth in the availability of higher quality reclaimed water and opportunities for water reuse. In the three years to 1998/99 annual capital investment in wastewater treatment trebled to $195M and is expected to reach $300M in 2000/01 (WSAA, 1999).

2. RECENT HISTORY AND PROJECTIONS OF WATER REUSE IN AUSTRALIA

Projections in 1994 of water reuse by major Australian water utilities (Thomas *et al.,* 1997) help illustrate the acceleration in reuse. The 1994 estimate of direct reuse of sewage effluent was 18 GL (1%) with growth to 64 GL (3%) in 2020. These figures excluded land treatment. Thomas *et al.* regarded these projections as minima, based on confirmed schemes or adopted targets, and suggested that if the recommendations of their report were adopted reuse figures would increase. Over the same period annual sewage volumes were projected to increase by 800GL (nearly 50%) and the increase in discharge of effluent to coastal waters by 600 GL (50%), placing pressure for improved treatment to contain pollutant loads to the environment.

In a subsequent scenario study (Thomas *et al.*, 1999), total Australian water use in 2020 was restricted to the estimated sustainable yield of 27,400 GL, and projected gross domestic product was maintained by transfers from lower to higher valued industries and gains in water use efficiency, with projected savings in water use of 5,600 GL (17%). Although only 12% of current Australian water use is in urban areas, increases in urban water use efficiency through recycling alone have potential to very significantly exceed 17%. Urban water utilities with greater capacity to pay for water, advanced technical expertise and more easily monitored environmental performance, are likely to lead the way in improving water use efficiency (Speers,1999). Recycling is among the most cost-effective ways of improving water use efficiency in cities where water resources are tightly constrained.

A survey by the author in 1999/2000 found that current sewage effluent reuse exceeds 7 % (Table 1a), significantly exceeding Thomas's 1994 projections. Current firm (minimum) projections are for effluent reuse to increase by 28GL/yr/yr, ie. to double over the next 4 years (Table 1b). According to WSAA (1999) there was an increase in the annual volume of effluent reused or recycled by ~ 13GL from 1997/98 to 1998/99. National reuse is equivalent to the volume of water supplied annually by the 8th largest Australian supplier of water (City West Water Ltd). There has been a uniformly steady increase in the proportion of wastewater reused for large water utilities in Australia (Tables 1b and 2), however the starting points have been very different, with some clear leaders in the field. Only three of the largest 21 water utilities reused more than 10% of their wastewater; Goulburn Valley Water reused 72% in 1998/99, Coliban Water 41%, and Melbourne Water 19%. In the same year three non-major urban water utilities (NMU's) achieved 100% reuse; Albury, Bathurst and Lower Murray. NMU % reuse currently exceeds that of major urban utilities.

Table 1a. Water reuse from water utility STP's in Australia, 1996-1999

region	year	effluent GL/yr	reuse GL/yr	reuse %
QLD	1998	328	38	11.6
NSW	1996	548	40.1	7.3
ACT	1998	31	0.25	0.8
VIC	1999	367	16.9	4.6
TAS	1999	43	1	2.3
SA	1998	91	9	9.9
WA	1999	109	6.6	6.1
NT	1998	21	1	4.8
Aust.		**1538**	**112.9**	**7.3**

Source: Susan Leahy (SA), Andrew Mills(NT), Catherine Clark, Max Thomas, David Gregory, Peter Donlon, Peter Byrnes, Pam Kerry (Vic), Peter Szlapinski (ACT), Howard Gibson (Qld), Warren Lee (Tas), John Anderson, Carol Howe (NSW), Lindsay Edmonds (WA) (QWRS, 1999; DPIWE,1999; Leahy *et al.*, 1998)

Table 1b. Water reuse from water utility STP's in Australia, 2001-2008

region	year	effluent	reuse		increase in reuse*	
		GL/yr	GL/yr	%	GL/yr/yr	%/yr
QLD	2008	400	118	29.5	8.0	1.8
NSW	2005	576	97	16.8	6.3	1.1
ACT	2001	30	0.95	3.2	0.2	0.8
VIC	2005	386	68	17.6	8.5	2.2
TAS	2005	45	3	6.7	0.3	0.7
SA	2003	91	23	25.3	2.8	3.1
WA	2005	142	13.5	9.5	1.2	0.6
NT	2004	21	5	23.8	0.7	3.2
Aust.		**1691**	**328**	**19.4**	**28.0**	**1.9**

Source: As per Table 1a * increase from date in Table 1a

Table 2. Percentage of wastewater reused from WSAA and NMU member STPs

	1996/97	1997/98		1998/99	
	WSAA	WSAA	NMU	WSAA	NMU
mean	4.9	6.6	n.a.	7.0	n.a.
median	4.0	4.7	6	5.0	10
min.	0	0	0	0.1	0
max.	65	69	100	72	100

Source: WSAA (1999), AWA (2000)

Recycling therefore represents a very significant 'new' irrigation or environmental water resource, which may assist high valued agriculture near urban areas. Reclaimed water has the advantage of flowing uniformly throughout the year and being relatively consistent in quality, having been through a treatment chain with some quality assurance (unlike inflows from some catchments to reservoirs for urban water supplies). With winter storage, either in aquifers or surface dams, this can represent a valuable economic commodity, as well as having intrinsic values in preserving environmental flows where it substitutes for mains water use, and in protecting surface waters from pollution by eliminating sewage discharges to sensitive water bodies.

Other sectors, notably mining, are also significant re-users of water (Table 3, Figure 1).

Table 3. Annual volumes of Australian water reuse by sector (GL)

	93/94	94/95	95/96	96/97	97/98	98/99
water supply[1]	63	69	72	82		
WSAA[2*]					110	124
WSAA[2**]				66	89	102
mining[1]	20	20	24	40		
elec/gas[1]	4	5	6	6		
other[1]	7	7	7	6		
total[1]	94	101	109	134		
effluent[2]	1222	1206	1320	1350	1345	1450

Source: [1]ABS (2000), [2]WSAA (1999) *p. ix, **figs 8.8 & 6.7

In the dry low-density cities such as Perth, Canberra and Adelaide, effluent discharge is only about 50% of the mains water inflow, as the other half of water is used on gardens and parks. If irrigation water was supplied as reclaimed water via dual reticulation from localized treatment plants, this would eliminate surface discharges and halve diversions of fresh water from the cities' water supply catchments. For the wetter and more densely populated cities, exterior water use is a smaller fraction of water demand, so sewer discharges are a higher proportion of mains water diversions (eg Sydney 75%). With a demand for urban irrigation water much smaller than the supply of effluent, other reuses say within and by industry, eg for cooling water, piping to rural irrigation areas, or treatment and release to reinvigorate streams and wetlands, are required to generate economic or environmental reuse value.

Country towns with sewerage or common effluent schemes and surface or aquifer storage, except in very wet areas are able to generate 100% reuse of reclaimed water for watering golf courses, ovals, and parks, as well as local commercial crops.

Reuse projects and plans for urban stormwater and rural irrigation drainage, with some exceptions, are currently sparse. These represent significant opportunities to generate new non-potable water resources in arid areas, where such supplies have high value.

To date reuse in Australia has apparently been unimpeded by health or environmental incidences, and public acceptance of non-potable reuse has been high. Guidelines for reuse of effluent as well as of biosolids are in place in most states and are integrated under the National Water Quality Management Strategy. (Incidentally, the proportion of biosolids reused in agriculture from effluent treatment plants in Sydney exceeds 97%, and nationally about 70% of biosolids are reused (WSAA, 1999).) However there are many concerns over the sustainability of effluent reuse and emerging issues with water quality that need to be addressed at specific sites to give proponents of reclaimed water reuse projects confidence that the intended outcomes will be achieved. It is also noted that a failure at even one site may do much to damage implementation of water reuse nationally. For this reason it is proposed that a national water reuse research program be implemented to undergird reclaimed water reuse in Australia. This is expected to focus on non-potable reuse initially, and subject to demand, to consider potable reuse later.

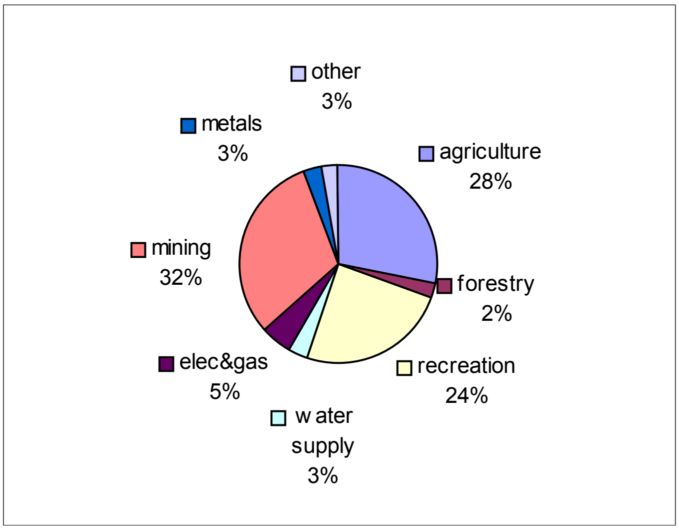

Figure 1. Reuse of effluent in Australia by economic sectors. *Source:* ABS(2000)

3. ISSUES IN WATER REUSE

The main issues in water reuse which can have a significant effect on the continued demand for recycled water and the need for recycling are:

- public health
- environmental sustainability
- quality of food products
- social acceptance
- treatment technology capability and reliability
- monitoring systems
- economics of recycling, and
- availability of expertise.

Risks involved in water recycling may be better understood and reduced through research to enable better guidelines (Anderson *et al.*, 2000), greater public confidence, enhanced and better focussed investment and development, preservation of natural resources, adoption of appropriate and more economic technologies, and greater knowledge which has an export value. Research may also defend against investment and public confidence disasters, which if they occurred would have severe local and national implications for the water industry.

4. WATER RESEARCH NEEDS

A pilot survey was undertaken by the author on behalf of AWA on water reuse research priorities in Australia. This involved one to two representatives of each state and territory, generally members of the national executive of the AWA Water Recycling Forum or others with extensive experience in water reuse. The survey was distributed by email in Sept. 1999 and responses were received by email or fax through to Dec. 1999. All representatives were asked to respond on behalf of their state or territory, and assign high, medium or low priority to each of 37 branches of research described by a phrase or word, under three broad headings; water quality, health and environment, and social/legal/economic. Definitions of water recycling, research, investigations and demonstration projects were provided with the survey form. This was intended to provide an indicator of the needs for research, and until repeated on a broader sample cannot be claimed to be an accurate reflection of national demand. Certainly in some localities there are specific research needs which have very high priority, which are not recorded as having a high priority on this list. An overall economic evaluation of benefits and costs of reuse research is warranted, and is beyond the scope of this paper.

The research priorities that emerged are presented in Table 4. This survey indicates that the highest research priority was to provide the necessary information to address those factors influencing public acceptance of reuse. In comments received on the questionnaire, as well as supported by other high priority fields, this takes into account potential health effects on consumers and on growers and relates to market acceptance of produce grown with recycled water. Compiling a summary of current research was also seen to be a high priority. Demonstration projects at which costs were documented were also seen as valuable in reducing other uncertainties that were perceived as barriers to recycling.

Beyond this, rankings in Table 4 reflect a blend of environmental and public health issues in which further information would reduce risks of adverse outcomes, or improve the management of recycled water so as to produce sustainable operations. Few priorities were devoted to treatment processes, with the exception of disinfection effectiveness, algae and algal toxin removal, and suspended solids removal. Most were more motivated by understanding outcomes, apparently with a view to improve treatment processes to attenuate the most mischievous contaminants in recycled water.

Table 4. Results of a survey of Australian water reuse research priorities

Rank	Field of Research	Theme
1	factors affecting public acceptance of reuse	H,E,S
2	viruses	H
3	public health impacts of reuse	H
	impacts on food quality of reuse on crops	H,E
4	publishing a summary of existing research	All
	economics of reuse	Ec
5	disinfection effectiveness	H
	environmental impacts of reuse	E
	salinity	E
	pathogenic bacteria	H
	legislation and regulations	H,E
6	algae prevention/removal	E
	impacts on soils	E
	impacts on groundwater	E
	impacts on fresh surface water	H,E
	sodicity	E
7	suspended solids removal	H,E
8	algal toxin removal	H
	packaging existing information for regulators	H,E
	cryptosporidium	H
	insurance for reuse schemes	All
9	endocrine disruptors	H,E
	impacts on estuarine and marine waters	H,E
	nitrogen	E

Themes: E = environment, Ec = economics, H = public health, S = sociological

5. EXISTING AUSTRALIAN REUSE RESEARCH

A second questionnaire was circulated in pilot form in Sept. 1999 to obtain a cross-section of current water reuse research projects. Table 5 lists these projects. Land and Water Resources R&D Corporation funded a further 7 recently completed projects.

This list is provides a sample of the current Australian water reuse research portfolio, and these projects alone reflect an annual expenditure of $2.9M. Coordinated into a national program, this expenditure could have enhanced benefits through use of the same monitoring installations and samples for multiple purposes, and integration of research results. It is suggested that more comprehensive information on aims, methods and results of these and other research projects be posted in a web-accessible database on the AWA Water Recycling web page to make new knowledge more accessible. This would be periodically updated and this task could be one of the activities in a new Australian research program on water recycling.

Table 5 Current and recent water reuse research projects in Australia

Title	Principal Researcher	Dates	Theme
Attitudinal component domestic water use study - Perth	Syme	98- 00	S
Integrated cost-effective urban water system - Urban water - Ellenbrook Estate, Perth	Speers	98- 01	E/Ec
Innovation in urban water recycling - Mawson Lakes, SA	Marks, R	98- 09	E/Ec
Vineyard trellis posts from eucalypts grown using effluent, Mildura, Vic	Cookson	99- 00	E/Ec
Insect pest monitoring in effluent irrigated eucalypt plantations, Koorlong, Vic	Floyd	since 94	E
FILTER - filtration and cropping for land treatment and effluent reuse, Griffith, NSW	Jayawardane	94- 01	E/Ec
Whole irrigation area salt management, Griffith, NSW	Blackwell	97- 01	E/Ec
Trees for profit - (effluent irrigated) Shepparton, Vic	Baker	95- 00	E/Ec
Fate of sodium under saline - sodic groundwater and effluent reuse, Tatura, Vic	Surapaneni	97- 00	E
Fate of nutrients in effluent-irrigated pasture, Shepparton, Vic	Kerry	90- 95	E
Safety of wastewater irrigation of dairy farms, Pakenham, Vic	Kerry	99- 02	H
Factors affecting success of programs for sustainable water recycling, New Haven Village, SA	Cromar	99- 01	H
Community and water reuse: a critical sociological analysis, New haven Village, SA	Marks, J	00- 03	S
Aquifer storage and recovery of stormwater, Andrews Farm, SA	Dillon	92- 99	E
Aquifer storage and recovery of reclaimed water, Bolivar, SA	Martin	97- 01	E,H, Ec
Wagga Wagga effluent plantation project	Myer	94- 00	E,Ec

Themes: E = environment, Ec = economics, H = public health, S = sociological

A comparison of the priority needs for research and the types of research results available or currently being generated show significant gaps in reuse research related to health, product quality, environmental fate of constituents, economics and sociology. Even areas where there are projects, these are generally focused rather narrowly, and compilations of current knowledge are also needed.

6. INTERNATIONAL RESEARCH PROGRAMS

There is much water reuse research undertaken within R&D programs around the world. The first real attempt to integrate and add value to these was initiated by the Water Environment Research Foundation. WERF established a Water Reuse Program, which at Oct 1999 contained 12 projects, most aimed at improving environmental monitoring of pathogens in reclaimed water, with others surveying non-potable reuse management practices, and identifying the effects of multiple stressors on aquatic ecosystems (WERF, 1999).

The 'WateReuse Association of California' has among its main strategic goals to foster additional research and development in water recycling and the dissemination of the findings. It does this through the *'WateReuse Foundation'* which it established to facilitate R&D and education on water recycling. In June 1998, the Foundation's research committee conducted a workshop to assess research needs in conjunction with the University of California Water Reuse Research Conference (WateReuse Assoc of California, 1998). From the workshop came six research themes: public health; water quality; economics and risk management; treatment and new technologies; aquatic environment; and public attitudes.

Not surprisingly these closely resemble the research priorities identified in the Australian survey. However Californian interests were higher in; disinfection byproducts, fate of pharmaceutical substances, real time pathogen monitoring, contaminant attenuation in soil-aquifer treatment, developing a certification process for new treatment technology, use of recycled water for restoration of wetlands and identifying mechanisms for assigning costs to beneficiaries of water reuse projects.

Wastewater reuse research in Europe is undertaken within individual countries R&D programs, and through large integrated projects of the European Commission, in the Energy, Environment and Sustainable Development Program under the Key Action: 'Sustainable management and quality of water', at item 1.3.2 Waste water treatment and re-use (European Commission, 2000). Fourteen projects in this category were funded in 2000, most of which related to reuse of water. The thrust of the research continues to be oriented towards innovative wastewater treatment methods. However there is a substantial body of research in progress concerning methods of measurement (including biomarkers) of endocrine disruptors, pharmaceuticals, surfactants, and metals and their fate in wastewater treatment plants and in the environment (Waste Water Cluster, 2000). This reflects the substantial quantities of effluent discharged to European rivers leading to indirect potable reuse, and potential ecosystem impacts.

Intl.Water Assoc Specialist Group on Wastewater Reclamation, Recycling and Reuse also aims to stimulate research and disseminate outcomes oriented to establishing guidelines, demonstrating sustainable water management and developing planning systems that account for environmental impacts.

7. R&D GAPS FOR AUSTRALIA.

Anderson *et al.* (2000) suggested an integrated international framework for balancing risk and affordability in developing national guidelines for water recycling. Recognising that our knowledge is not perfect, and that we need to make decisions based on best available information, drawing on the international knowledge base is vital. An Australian contribution is also warranted, in order to resolve local issues, and by conducting research (based on fundamentals) as opposed to only trials (to supply topical solutions) we can contribute in the international arena. High quality research conducted in parallel with trials will allow the risks and benefits of recycling to be more clearly defined, assisting in the evolution of rational state and national recycling guidelines, as well as contributing to the basis needed by countries in transition who do not have the requisit research infrastructure and broad skill base.

An examination of the research priorities identified in Table 4, shows that some of these are site-specific (eg community acceptance, economics), some are regionally transferable (eg fate of recycled water constituents within crops, soils, and water bodies say within a biogeoclimatic zone), and some may be internationally transferable (eg effectiveness of treatment technologies). However Australia currently lacks a coordinated national research program in water recycling, although as seen from Table 5 there is substantial uncoordinated expenditure in this field.

It is proposed that Australian water utilities, and natural resources agencies of Australian states and the Commonwealth together establish a concerted national water recycling research program, which at 1c/KL would provide more than $1M pa to focus recycling research on the most pressing issues and ensure appropriate communication of research results. The impact of a failure (eg epidemic outbreak), loss of land productivity, or failure to curb eutrophication of fresh or estuarine waters, would have far greater costs locally than that of a national program, which would help avert such failures. Development opportunities would be foregone Australia-wide if public opinion turned against recycling. A proposal for such a research program is currently in preparation, and those with an interest in participating in this process are invited to contact the author.

8. ACKNOWLEDGEMENTS

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