Economics of Wastewater Treatment and Recycling: An investigation of conceptual issues

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Abstract

In the context of continuous droughts, the search for alternative water sources and increasing environmental restrictions on discharge of treated wastewater into natural water bodies, treated wastewater recycling offers a potential solution. In this paper the methods needed to assess the questions - to what extent treated wastewater can complement the existing water sources in different sectors and at what cost - are discussed? It was concluded that a comparative Benefit Cost Analysis of different combinations of uses and treatment levels would be a critical component in the development of a decision support tool which could be used by urban planners and water authorities. It was also found that community acceptance of recycled water, distribution of costs and benefits of recycling and its broader impact on regional development are issues that need to be considered, along with the economics of wastewater recycling.

Keywords: *Wastewater, recycling, water quality, pricing, allocation, urban design*

1. Current Water Situation in Australia

More than 80 per cent of Australian population (approximately 19 million) lives in cities that are within 100 km of the coast (WSAA.2005:4). In spite of this fact, the water policy debate has concentrated mainly on agricultural water shortages. This occurs because 67 per cent of all water extracted is used in agriculture and only 9 per cent is used by households and 7 per cent by the manufacturing industry. Until the 1990s water authorities have kept pace with the growth in population and its water requirements. However, in recent years the gap between supply and demand has grown and the marginal costs of providing additional supplies are rising sharply. The population of Australia's major cities is predicted to increase by 35 per cent, or 4.5 million people, by the year 2030 (Australian Bureau of Statistics and State Government planning documents. 2005). The combined impact of increase in demand from population (see Table 1), allocating more water for river health and possible decreases in water yields due to anticipated droughts and climate change makes it necessary to manage both the supply and demand for water.

Table 1: Projected population and water consumption in Australia's major cities

City	Current Population (000s)	Projected population in 2030 (000s)	Increase (%)	Adjusted unrestricted consumption (ML/yr)
Adelaide	1 090	1 182	8	190 383
Brisbane	931	1 509	62	196 095
Canberra	357	486	36	51 208
Darwin	101	168	67	35 142
Gold Coast	472	800	69	69 899
Hobert	188	215	14	40 679
Melbourne	3 497	4 573	31	498 295
Lower Hunter	496	585	18	72 231
Perth	1 453	2 177	50	262 359
Sydney	4 189	5 592	33	647 158
Total	12 774	17 287	35	2 063 448

Source: WSAA-Position Paper No.01, October 2005-Testing Water-Urban water in our growing cities-the risks, challenges, innovation and planning

2. The Urban Water Balance Sheet

Taking the current drought period as an opportunity, the urban water industry has developed water resources strategies for each major Australian city. These strategies have a strong supply-side focus and include inter-basin transfers, accessing groundwater and desalination, sourcing water from water markets and increasing use of recycled water. However, as these strategies take some time to implement governments currently rely on demand-side programs to reduce per capita use, which mainly involves improving water use efficiency.

The urban water balance (see Table 2) seeks to maintain equilibrium between increases in demand for water due to population growth and potential reductions in yield from existing water

sources, with additional and new sources of supply. Without the supply-side measures, a water deficit of 854 GL would result by 2030 (WSAA. 2005:24]. The limitations of relying on ongoing water efficiency programs to close the gap between demand and supply-side measures – with both new sources of water and alternative sources of water - are expected to enable Australian cities to grow and prosper into the future. New sources of water include, the transfer of water from adjoining catchments, accessing agricultural water through water markets, reducing water losses from run off, leakages and water lose management, construction of desalination plants, expanding ground water sources, better use of existing dams that are currently not being used for potable purposes and extracting additional water from rivers. Alternative supplies of water mostly involve recycled water from wastewater and storm water that can be used as a substitute for potable water.

Table 2: The urban water balance sheet

	Population (million)	**Available Water (GL)**	**Consumption (GL)**	**Total (GL)**
Current				
Population of Australian capital cities (plus Gold Coast and Lower Hunter region)	12.8			
Yield		2175		
Unrestricted consumption			2063	
Existing surplus				**111**
Future-2030				
Population	17.3			
Yield (25% reduction to account for potential climate change impacts)		1631		
Consumption based on 2004 per capita			2811	
Water deficit				**1180**
Measures identified in urban water strategies				
New sources of water		684		- 496 GL
Alternative sources of water		195		- 301
Water efficiency measures			-326	
Total		**2510**	**2485**	**25**

Source: [WSAA. 2005:25]

3. Recycling of Wastewater

While the term "recycled water" is loosely defined in this paper it only refers to treated urban wastewater. Wastewater use in agriculture is a common phenomenon in developing countries where more than 80 per cent is untreated. There farmers face various health problems associated with close contact to wastewater and over the time, the practice leads to decrease in the land

productivity, due to increased soil salinity and loss a of cropping options. However, in developed countries like Australia all the wastewater generated is treated according to Environment Protection Agency (EPA) standards, before it is released into natural water bodies. In such countries, there is the potential to use treated wastewater in sectors other than agriculture. Recycled water can be treated to a number of different standards (class A, B, C and D) (See Annex A for more information). Class A recycled water is the highest quality and is considered safe for use in human food crops, including those eaten raw, whereas the least treated waster is class D which has limited use for irrigation of woodlots and flowers. Each recycling standard has a number of associated risks and its use should be based on a sound economic analysis that takes into account all the environment and social externalities generated from wastewater recycling.

3.1 Current wastewater recycling in Australia

According to Australian Bureau of Statistics [ABS], the volume of wastewater recycled has increased by 300 per cent since 1996-97. In 1996-97 there were 134 GL of water recycled in Australia, making up less than 1 per cent of total water used that year. By 2000-01, this volume had increased to 516 GL. However, this still accounted for less than 1 per cent of total water use. Agriculture was the largest user of reuse water in 2000-01, accounting for 423 GL or 82 per cent of all reuse water used in Australia. Currently in Australia, there are over 580 different recycled water schemes operating. Approximately 230 schemes use recycled water in the urban environment (e.g. golf courses and recreational parks). Another 80 service industry (e.g. washing and cooling) and additional 270 are agriculturally based (e.g. horticulture, forestry, pasture, cotton, flowers, viticulture and cane) (ARRIS. 2004).

Recycled water use could increase in the coming years. Governments of different states have set ambitious targets to increase recycled water (see Table 3) as substitutes to potable water supplies.

Table 3. Targets set for increase in recycled wastewater use in major Australian cities

City	Percentage of use from recycled water (2001-02) (%)	Specified Target
Melbourne	2	20 % by 2010
Sydney	2	12 % by 2011
Adelaide	11	30 %
Brisbane	6	Target arising from water planning
Perth	3	20 % by 2012
ACT*	5	20 % by 2013

Source: Synergies Economic Consulting
*ACT: Australian Capital Territory

3.2 Key drivers for wastewater recycling

Fresh water is a limited resource which has increasing competing alternative uses for it. The less expensive supply options have already been exhausted and access to new water sources involves increased incremental costs. Desalination and recycling are emerging as the next major options to fill the widening gap between demand and supply (Hamilton *et al*. 2005:185). A number of other factors have driven local governments and water authorities to invest in and make use of alternative water sources. An important factor has been the pressure from the environmental

lobbies to minimize the potentially negative impact of nutrients released into the natural water bodies that come from water treatment plants. In addition, the substitution of water used in peri-urban agriculture and urban irrigation can free up water for environmental purposes. Further, wastewater recycling is driven by the need to improve the economic development of regions by creating employment and increasing the property values. For example in the Lockyer Valley proposal (South East QLD Recycled Water Task Force. 2003) the social advantages in employment and populations for the regions by using reclaimed water and the financial gains for individual property owners through increase in property value (of $0.8 million per property) were identified.

4. Economic Characteristics of Recycled Wastewater

Any good that is scarce and is something which one would choose more of if one could is an economic good (Macmillan dictionary of Modern Economics). Wastewater is an economic good in developing countries like India, but may not yet be one in Australia, as people are not choosing more of it at present. However, with emerging technologies, the scarcity of fresh water and changing perceptions, wastewater may emerge as a valuable resource. According to Muir (2006), wastewater will become scarce over time because of increased use or reduced discharge into sewers. Therefore, he argues that authorities need to avoid “locking in” low value uses of recycled water and need to take a long run view and develop mechanisms for allocative efficiency.

A number of factors influence wastewater recycling. These include

1. Centralised wastewater treatment systems, the location of the treatment plants, the availability of space in and around cities and the topography all restrict the use of wastewater to certain areas and for specific purposes. The high transportation costs of the wastewater from treatment plants to the point of use may encourage use of existing infrastructure (like irrigation canals) so that wastewater is increasingly used in agriculture or on market gardens in the peri-urban areas of the city, rather than in households or by industry.
2. There are substantial barriers to entry in the field of wastewater recycling. Wastewater is often operated and owned by a single entity, like the Water Board or sewage treatment plant, which is often the retailer. Also, wastewater recycling often requires a dual reticulation system which is often inefficient to duplicate (Muir. 2006).
3. There are both positive and negative externalities associated with wastewater recycling. The positive externality is: environmental benefits from reduced discharge of saline wastewater into natural water bodies. The negative externalities include potential groundwater pollution and increase in soil salinity if used for irrigation and potential unknown ill effects on human health if used for potable uses. Recycled water could well be subsidized to internalize the value transfer for avoided costs between those avoiding the costs to those generating the benefit (users of recycled water). However, any subsidy may well lead to an inefficient allocation of resources.

5. Research Gaps in Wastewater Recycling

The focus of most wastewater related research has been on the technical and related issues of improvements in water quality and in minimizing environmental and health impacts. There has

been little information produced on wastewater recycling from an economic and a social perspective. In particular, the costs and beneficial outcomes have been imprecisely quantified (DSE. 2005). The key issues that are yet to be looked at in wastewater recycling relate to pricing and allocative efficiency.

5.1 Pricing recycled water

Radcliffe, (2003) argues that the costs and pricing mechanisms for wastewater are not transparent, as the true cost of irrigation, potable and recycled water is not reflected in the current prices. Radcliffe estimated the disparities in pricing water from recycling schemes ranged from 7 to 83 cents per kl, compared to the true cost of reclaimed water that ranged from $1.45 to $3.00 per kl. Radcliffe attributed these differences to unaccounted costs and the fact that environmental externalities are not costed and internalized. According to Muir (2006) price signals from the use of recycled water should be set at the long run marginal costs of supply. If this is done then appropriate decisions on existing stand alone schemes or the comparison of different proposals can be made.

5.2 Allocative efficiency

There are no clear guidelines on what factors need to be considered when allocating the recycled water to different sectors, so that overall economic efficiency is maximized. According to Freebairn (2003:1) economic efficiency is maximized by allocating limited water among alternative uses so that marginal social benefits are equated across the different uses. Formally:

$$MSB_l = MSB_k \text{ for all } l \text{ and } k$$

where MSB is the marginal social benefit and l and k are the different uses of water (i.e. irrigated crops, industry, household non-potable use and public recreational areas like parks).

5.3 Other areas of concern

A number of other areas also require research. Hamilton (2004:204) suggests research should be directed to the potential expansion of wastewater irrigated products and their acceptability by consumers. In addition, risk assessment modeling related to soil and human health issues are in need of further research. An analysis of recycled water schemes in relation to the broader regional infrastructure planning is needed (Kularatne. 2005:26). Po Murni (2004:22) suggests that social research in understanding the basis of public perceptions of water reuse and the psychological factors governing their decision making processes is essential in the formulation of any reuse policy.

6. Current Research

Given the current water situation in Australia described and the research gaps identified above, it would appear that a wide ranging study on wastewater is justified. Adding weight to this belief are the actions of Australian state governments in setting targets to increase wastewater recycling and a number of wastewater recycling schemes/projects being prepared. Under the National Water Quality Management Strategy, the National Resources Management Ministerial Council (NRMMC), the Environment Protection and Heritage Council (EPHC) and the National Health and Medical Research Council (NHMRC) have endorsed the updating of National guidelines on water recycling and storm water management and reuse, particularly for large scale treated sewage and grey water to be widely used. These include residential discretionary uses; irrigation for urban open spaces, agriculture and horticulture; fire protection systems and industrial uses,

including cooling water. While benefit cost analysis are undertaken on isolated wastewater recycling projects, these are inadequate in determining the allocative efficiency across sectors. The purpose in this Section is to outline a plan which could be used to address some of the research shortfalls identified above.

The questions that need to be immediately addressed are:

1. What are the different sectors within a defined region which wastewater can efficiently be recycled, such that it contributes to the overall national productivity or efficiency?
2. What are the different options through which wastewater recycling efficiency could be increased - treating it to a level below class A depending on its end use such that it still complies with the EPA standards, decentralization of treatment, let the downstream people use it?

The first question relates to identifying sectors within which water recycling is viable, while the second questions relate to the evaluation of different recycling options.

To that end a hypothesis that could be tested is: Treated wastewater recycling is not a viable economic option to deal with the problems of water scarcity and to reduce the pollution caused by nitrogen discharge of wastewater into the natural water bodies.

Wastewater has a number of alternative uses and each alternative is characterized by flow of benefits and costs over time. As a consequence, Benefit-Cost Analysis is arguably the most appropriate method to compare these different alternative uses, to choose the most socially desirable ones and improve the logic involved in making decisions on water recycling.

Benefit-Cost Analysis is defined as a method to assess the relative desirability of competing alternatives, where desirability is measured as economic worth to society as a whole (Sinden & Thampapillai. 1995:1). It is a systematic approach to decision making and applies economic theory to choices through the problem solving, scientific method. Alternatives are defined, their outcomes identified and valued, their overall net benefits to society are estimated and compared. Benefit-Cost Analysis can help reduce the complexity of a decision to a manageable level, as it involves clear identification of benefits and costs and their flow over time. The separate steps of the procedure help in understanding problems and the ways to resolve them.

Assuming that all wastewater is treated to Class A standard, three sectors can be chosen for a comparative Benefit-Cost Analysis. They are:

1. Horticulture: Irrigated agriculture accounts for approximately 67 per cent of Australia's total water use (ABS, 2004). Horticulture and viticulture accounts for 13 per cent of the total volume of water used by irrigated agriculture (vegetables 14 per cent, fruit 5 per cent and grapevines 4% per cent) (HAL. 2003). A number of wastewater recycling schemes for horticulture are already in operation (see Radcliffe. 2003) and some other large schemes are being considered or developed. Horticulture is one of the high dividend yielding sector and as most market gardens are close to city it makes (economic) sense to use wastewater.
2. Household use: Demand for urban water is generally inelastic and not particularly price sensitive. However, household water use may be divided into discretionary (outdoor) and

non-discretionary (indoor) uses. The discretionary water use is more elastic than non-discretionary use and hence more price sensitive. Recycled water may be largely promoted for household discretionary uses.

3. Industrial use: Industries, like power plants, use large quantities of potable water. Demand for water from industry is generally price inelastic and in many cases forms only a small component of their total costs. However, the costs of water restrictions for industry are very high for them and for the economy. Therefore continuity and reliability of supply is often of central importance (Muir. 2006)..

To ascertain whether any of the potential uses for recycled water are economically viable would require a benefit cost ratio of greater than one at the social discount rate. However, a comparative Benefit-Cost Analysis among the three would allow for prioritizing the allocation among different sectors. This may also assist in developing a decision support tool in which an integrated plan for water allocation for different sectors and amount of water that can or should be recycled could be developed.

7. Conclusion

Comparative Benefit Cost Analysis across different sectors could be of use in the development of a decision support tool which could be used by urban planners and water authorities. The tool could be used to determine the sectors where treated wastewater can be efficiently recycled. This would occur where marginal social benefits are higher than the marginal social costs (i.e. MSB>MSC). The decision support tool can further be used to develop different scenarios with water treated to varying levels (i.e. Class A, B, C, D), and determine the most cost effective use while complying with the Environmental Protection Authority standards. However, over the long run, the more important contribution of the Benefit Cost Analysis would be, understanding the problems of recycling itself.

As wastewater becomes a key resource in the coming years, the question will not be whether to recycle wastewater, but whether an option exists not to recycle. Under such a scenario, there is a need for all the stakeholders (wastewater providers and users) to work towards developing mechanisms to make recycling not just safe, but economically efficient with the right institutional mechanisms in place.

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Annex A

Classes of Recycled Water

Recycled water is fully treated and can be safely used for a variety of purposes appropriate to the level of treatment it has undergone. In Australia, recycled water is classified according to its quality and range of uses.

Class A
This is the highest quality of recycled water and is achieved after a tertiary treatment process combined with pathogen removal. The Department of Human Services has classified Class A recycled water as safe for use on irrigation for food crops - including those eaten raw. The Department of Human Services requires an extensive verification process to ensure Class A water can be guaranteed. Environment Protection Agency (EPA), Victoria also supports its use. Class A recycled water has the widest range of uses including:

- residential garden watering
- closed system toilet flushing
- process/cooling water for industry
- fire protection stores and reticulation systems
- irrigation of municipal parks and sports grounds
- water for contained wetlands or ornamental ponds
- food crops that are consumed raw or sold to consumers uncooked or processed
- all of the uses listed for classes B, C and D

Class B
A secondary treatment process, combined with some pathogen reduction is used to produce Class B recycled water. With strict management practices it may be used for the following:

- irrigation of dairy cattle grazing fodder
- livestock drinking water (not including pigs)
- wash down water for dairy sheds and stockyards (not including milking equipment)
- urban (non-potable) uses with restricted public access
- closed industrial systems
- all of the uses listed for classes C and D

Class C
A secondary treatment process combined with minor pathogen reduction is used to produce Class C recycled water. With strict management practices it may be used for the following:

- cooked/processed human food crops
- selected (raw/unprocessed) crops not directly exposed to recycled water (eg. apples)
- grazing/fodder for cattle, sheep, horses, goats etc.
- grazing for dairy cattle (subject to a five day withholding period after irrigation)
- urban (non-potable) uses with restricted public access
- closed industrial systems
- all of the uses listed for Class D

Class D
A secondary treatment process is used to produce water of this quality. Class D recycled water may be used for the following uses:

- non food crops such as woodlots, turf growing and flowers