WORKING PAPER 128

Wastewater Reuse and Recycling Systems:

A Perspective into India and Australia

Gayathri Devi Mekala, Brian Davidson, Madar Samad and Anne-Maree Boland

International Water Management Institute

FUTURE HARVEST
IWMI is a Future Harvest Center supported by the CGIAR

The University of Melbourne

Cooperative Research Centre for IRRIGATION FUTURES

Working Paper 128

Wastewater Reuse and Recycling Systems: A Perspective into India and Australia

Gayathri Devi Mekala
Brian Davidson
Madar Samad
and
Anne-Maree Boland

International Water Management Institute

IWMI receives its principal funding from 58 governments, private foundations and international and regional organizations known as the Consultative Group on International Agricultural Research (CGIAR). Support is also given by the Governments of Ghana, Pakistan, South Africa, Sri Lanka and Thailand.

The authors: Gayathri Devi Mekala is a PhD scholar enrolled at the University of Melbourne, Australia. Ms. Mekala's research is funded by the International Water Management Institute (IWMI) and Cooperative Research Centre for Irrigation Futures (CRC IF). She is currently studying the economics of wastewater recycling in Australia and India. Email: *g.mekala@pgrad.unimelb.edu.au*

Brian Davidson is a Senior Lecturer in the School of Resource Management at the University of Melbourne and is also associated with the Cooperative Research Centre for Irrigation Futures. He has over 20 years experience in teaching and researching many different issues in agricultural and resource economics. His research interests lie in understanding and measuring how water markets deliver services to users, how water can be shared amongst stakeholders and how the market failures evident in water and land can be evaluated. Email: *b.davidson@unimelb.edu.au*

Madar Samad is a Principal Researcher and Head of the India and Nepal offices of the International Water Management Institute (IWMI). He has more than 20 years experience as an Agricultural Economist dealing with research in the field of agricultural and rural development, project planning and evaluation, policy analysis and project management. Email: *m.samad@cgiar.org*

Anne-Maree Boland is Associate Partner at the RM Consulting Group. Anne-Maree has 15 years experience in dealing with natural resource and water management in Australian agricultural industries. This has included research and development in the areas of water use efficiency (WUE), salinity, waterlogging, recycled water and environmental management systems. Anne-Maree has experience in working with and establishing partnerships with diverse stakeholder groups (government, CMAs, water and agricultural industries).Email: *anne-mareeb@rmcg.com.au*

Mekala, G. D.; Davidson, B.; Samad, M.; Boland, A. M. 2008. *Wastewater reuse and recycling systems: A perspective into India and Australia*. Colombo, Sri Lanka: International Water Management Institute. 35p. (IWMI Working Paper 128)

/ water reuse / recycling / costs / wastewater irrigation / water use / water balance / water quality / water market / water scarcity / developing countries / developed countries / India / Australia /

ISBN 978-92-9090-691-9

Please direct inquiries and comments to: *iwmi@cgiar.org*

Contents

Summary

Wastewater irrigation is a common practice in developing countries of Asia and Africa and also in the water scarce regions of the developed world like Australia. In India, wastewater is used either raw or partially treated due to high treatment costs, whereas in Australia, treated wastewater is recycled in agriculture and other sectors in water scarce areas and regions with severe restrictions on disposal of treated wastewater effluents. In spite of ill effects of untreated wastewater on human health and the environment, the practice continues in India, as wastewater is highly reliable, nutrient rich and provides year-round income, employment and food security to the urban and peri-urban poor helping them escape poverty. Whereas in Australia, recycling is promoted to complement existing water resources and reduce nutrient disposal into natural water bodies. While the problems associated with wastewater reuse in India arise from its lack of treatment, in Australia often recycling projects do not take off even when wastewater is treated to tertiary level, due to a number of reasons like the "yuck factor", high cost of supply, higher salinity than normal river water, lack of information and trust in authorities. A number of issues related to wastewater reuse and recycling are yet to be understood and researched. A literature review shows the following research gaps: to identify opportunities and constraints to recycling; identify conditions required for wastewater markets to function efficiently; test commercial feasibility for wastewater treatment and recycling, pricing and supply mechanisms versus other options to complement existing water resources for urban areas; need for a uniform international approach to assess the feasibility of recycling, while providing flexibility for individual countries to vary requirements to suit local circumstances of affordability and risk; lack of decision support tools to efficiently allocate water and wastewater resources among different sectors, stakeholder objectives and priorities for wastewater recycling. With issues of climate change, increases in urban population and increased demand for water from competing sectors, wastewater recycling is becoming an important strategy to complement the existing water resources for both developing and developed countries and there are lessons, experiences, data and technology that can be shared for mutual benefit.

1. WASTEWATER – A GROWING RESOURCE

The use of treated, partially treated and untreated urban wastewater in agriculture has been a common practice for centuries in developing countries which is now receiving renewed attention due to rapid urbanization. By 2015, 88% of the one billion-person growth in the global population will occur in cities; the vast majority of this growth will occur in developing countries (UNDP 1998). An increase in urban water supply ensures an increased wastewater generation, as the depleted fraction of domestic and residential water use is only in the order of 15 to 25% (Scott et al. 2004: 2). The growing wastewater volumes render a cheap and reliable alternative to conventional irrigation systems. Figure 1 illustrates that increases in urban water supply coverage have been and will continue to be the highest in Asia followed by Africa, where absolute population figures as well as population growth are the highest. In this context wastewater is a resource that could be of increased national and global importance, particularly in urban and peri-urban agriculture. Hussain et al. (2001: 31) reports that at least 20 million hectares (ha) in 50 countries are irrigated with raw or partially treated wastewater.

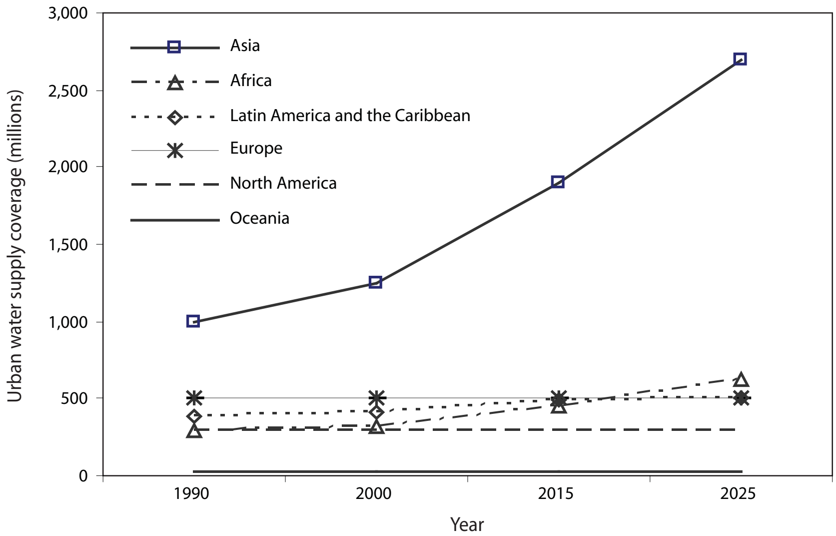


FIGURE 1. Growth in urban water supply coverage by regions of the world. *Source:* Scott et al. 2004: 3

1.1 Area under Wastewater Irrigation

To date, assessments have been carried out in Pakistan, India, Vietnam, China, Mexico and Jordan. In Pakistan an IWMI study estimated that there were 32,500 ha irrigated directly with wastewater (Ensink et al. 2004: 1-10). Strauss and Blumenthal (1990) estimated that 73,000 ha were irrigated with wastewater in India. In Vietnam, at least 9,000 ha of land were found to be irrigated with wastewater mostly to grow paddy and in and around 93% of the cities wastewater is used in agriculture or aquaculture (Raschid-Sally et al. 2004: 81). In Ghana, it was estimated that if only 10% of the 280 million cubic meters (Mm^3) of wastewater from urban Ghana could be (treated and) used for irrigation, the total area that could be irrigated with wastewater alone could be up to 4,600 ha. At an average dry season farm size of 0.5 ha, this could provide livelihood support for about 9,200 farmers in the peri-urban areas of Ghana (Agodzo et al. 2003). Mara and Cairncross

(1989: 187) estimated that 1.3 million ha were irrigated with wastewater in China. Scott et al. (2000) has estimated that in Mexico, about 500,000 ha of land is under wastewater irrigation. Hussain et al. (2001:31) report that at least 20 million ha in 50 countries are irrigated with raw or partially treated wastewater.

1.2 Rationale for Wastewater Irrigation

Whether recycling will be appropriate in a given situation depends on the availability of additional water resources, a desire or necessity to conserve rather than develop water resources, careful economic considerations, potential uses for the recycled water, the strategy of waste discharge and public policies that may override economic and public health considerations or perceptions (Mantovani et al. 2001). There are many ill effects of using untreated or partially treated wastewater like groundwater pollution, soil contamination, and the adverse effect on farmers and consumers of wastewater products. In spite of these facts, wastewater is widely used as it supports livelihoods and generates considerable value in urban and peri-urban agriculture. In many countries of the developing world, farmers use wastewater out of necessity and it is a reality that cannot be denied or effectively banned (Buechler et al. 2002). Highly specialized farmers use every free space with water access to cultivate cash crops. Although their plots are often small, irrigation (including with effluents, no matter what level of treatment, if any), allows these farmers to escape from poverty (Drechsel et al. 2002). Wastewater treatment in these countries is not possible due to low municipal/ government resources, and small, old or non-extendable sewerage systems.

1.3 Wastewater Use in Developed Countries

Wastewater reuse[1] is a common practice in developing countries of Asia and Africa and wastewater recycling[2] is common in water scarce regions of the developed countries such as the Australia, Middle East, south west of US, and in regions with severe restrictions on disposal of treated wastewater effluents, such as Florida, coastal or inland areas of France and Italy, and densely populated European countries such as England and Germany (Marsalek et al. 2002). Even in high rainfall countries like Japan, whose mean annual precipitation of 1,714 millimeters (mm), urban wastewater reuse is common due to high population density in some regions, which suffer from water shortages (Ogoshi et al. 2001). The developed countries have generated techniques and guidelines for safe reuse of wastewater, which can be adopted by the developing countries. After reviewing many overseas recycling projects, Radcliffe (2004) concluded that worldwide, water reuse is becoming an increasingly common component of water resource planning as the costs of wastewater disposal rise and opportunities for conventional water supply development dwindle.

1.4 Quality of Wastewater

Wastewater, if treated appropriately, has the potential to be recycled in a number of sectors. Recycled water can be treated to a number of different standards using different technologies depending on the quality required. As the quality goes up, so does the costs and there is a decrease in the risk (see Figure 2).

---

[1]Use of wastewater with no treatment or subject to primary treatment only

[2]Use of wastewater after secondary or tertiary treatment

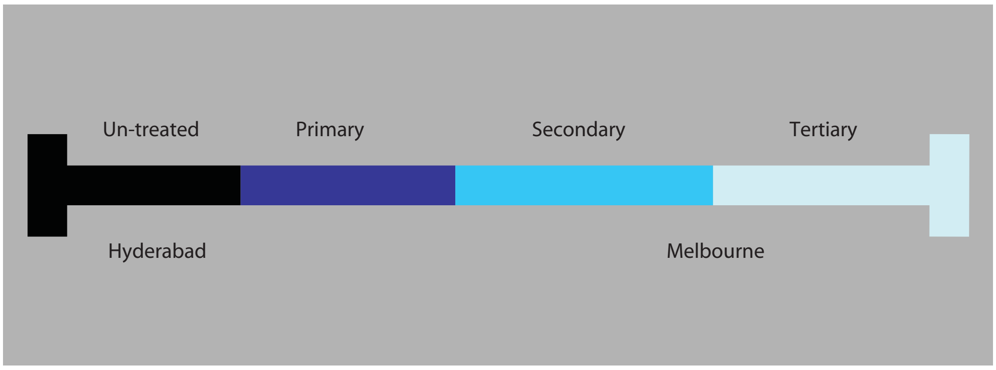


FIGURE 2. Stages in wastewater treatment.

Broadly, wastewater is treated to three levels, namely – primary, secondary and tertiary levels. According to the Environment Protection Agency (EPA), they are defined as follows:

1. **Primary treatment:** Treatment involving sedimentation (sometimes preceded by screening and grit removal) to remove gross and settleable solids. The remaining settled solids, referred to as sludge, are removed and treated separately.

2. **Secondary treatment:** Generally, a level of treatment that removes 85% of Biological Oxygen Demand [BOD] and suspended solids via biological or chemical treatment processes. Secondary treated reclaimed water usually has a BOD of <20 milligrams per liter (mg/L) and suspended solids of <30 mg/L, but this may increase to >100 mg/L due to algal solids in lagoon systems.

3. **Tertiary treatment:** The treatment of reclaimed water beyond the secondary biological stage. This normally implies the removal of a high percentage of suspended solids and/or nutrients, followed by disinfection. It may include processes such as coagulation, flocculation and filtration.

1.5 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 be one in Australia yet, as people are not choosing more of it at present. However, with emerging technologies, the scarcity of freshwater 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. Centralized wastewater treatment systems, the location of the treatment plants, the availability of space in and around cities and the topography – all of these factors 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 that is 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 costs avoided 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.

2. WASTEWATER RECYCLING IN AUSTRALIA

While the term "recycled water" is loosely defined, for the current research purposes, it only refers to treated urban wastewater collected by the urban sewage system and transported to the wastewater treatment plant of the city. Wastewater use in agriculture is a common phenomenon in developing countries where more than 80% is untreated. Farmers in these countries face various health problems associated with close contact to wastewater and over time the practice leads to a 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.

Wastewater recycling in Australia has resulted due to a combination of factors: urban population increase, decrease in rainfall, environmental concerns, need for greener water strategies and improved technology. In this section, we look at all these factors, research done in these areas and some crucial data.

2.1 Population and Water Use in Australia

More than 80% of the Australian population (approximately 19 million) lives in cities that are within 100 kilometers (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% of all water extracted is used in agriculture and only 9% is used by households and 7% 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%, or by 4.5 million people, by the year 2030 (ABS 2006). The combined impact of an 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. *Source*: WSAA 2005.

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
Hobart	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	2,063,449

Water extracted in Australia is overwhelmingly dedicated to the agricultural sector. As shown in the figures 3 and 4 below, urban water use, including household, manufacturing and other uses, accounted for only 16% of the 24,909 Giga Liters [GL] consumed in Australia in 2000–2001. The agricultural sector, by comparison, accounted for 67% of the water used. These figures give a breakdown of water use in Australia, the proportion of urban water used by different user segments, and how water is used by households. They illustrate where there is scope to reduce consumption or reallocate resources to achieve improved water resource outcomes.

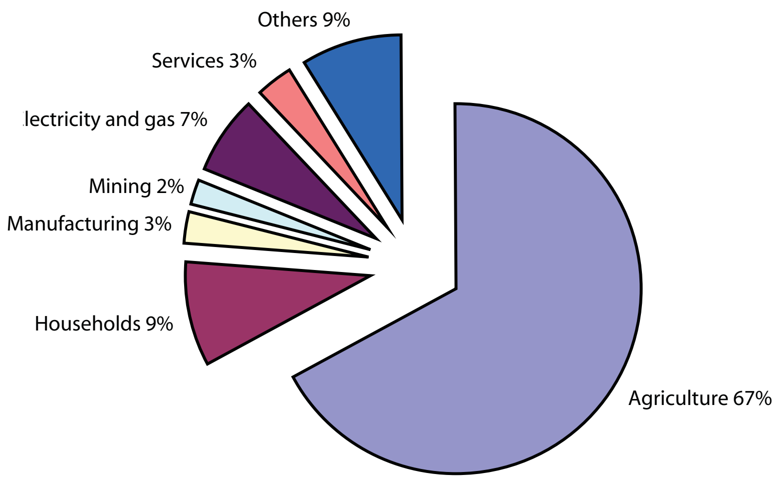


FIGURE 3. Water Use in Australia. *Source:* Chart data from ABS 2006.

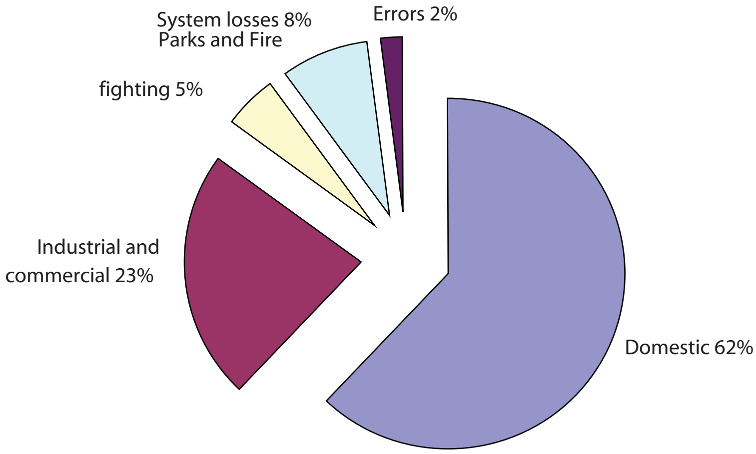


FIGURE 4. Urban Water Consumption (shown as a percentage of total consumption) in Australia.
Source: Chart data from ABS 2006.

2.2 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 interbasin transfers, accessing groundwater and desalination, sourcing water from water markets and increasing the 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 the demand for water due to population growth and the potential reductions in yield from existing water sources, with additional and new sources of supply. Without the supply-side measures, this would result in a water deficit of 854 GL 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 runoff, leakages and water loss management, construction of desalination plants, expanding groundwater 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. *Source:* WSAA 2005: 25

	Population (millions)	Available Water (GL)	Consumption (GL)	Total (GL)
Current				
Population of Australian capital cities (plus Gold Coast and Lower Hunter region)	12.8			
Yield		2,175		
Unrestricted consumption			2,063	
Existing surplus				**111**
Future - 2030				
Population	17.3			
Yield (25% reduction to account for potential climate change impacts)		1,631		
Consumption based on 2004 per capita			2,811	
Water deficit				1,180
Measures identified in urban water strategies				
New sources of water		684		- 496
Alternative sources of water		195		- 301
Water efficiency measures			-326	
Total		**2,510**	**2,485**	**25**

2.3 Current Wastewater Recycling in Australia

According to the Australian Bureau of Statistics (ABS), the volume of wastewater recycled has increased by 300% since 1996-97. In 1996-97 there were 134 GL of water recycled in Australia, making up less than 1% of the total water used that year. By 2000-01, this volume had increased to 516 GL. However, this still accounted for less than 1% of total water use. Agriculture was the largest user of recycled water in 2000-01, accounting for 423 GL or 82% of all recycled 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 are from the service industry (e.g., washing and cooling) and an additional 270 are agriculture based (e.g., horticulture, forestry, pasture, cotton, flowers, viticulture and cane) (ARRIS Pty Ltd. 2004). See Annex 1 for wastewater recycling projects in Australia and elsewhere in different sectors. Recycled water use could increase in the coming years. Governments of different states have set ambitious targets to increase recycled water supplies (see Table 3) as a substitute to potable water supplies.

Table 3. Recycled wastewater use in major Australian cities for 2005-06.

City	Total wastewater treated (GL)	Total wastewater recycled (GL)	Percentage recycled	Target (%)
Melbourne[1]	312	46.5	15%	20% by 2010
Sydney[2]	437	22	5%	16% by 2015
Adelaide[3]	70	14	20%	43% by 2025
Brisbane[4] from water planning	107	5	4.8%	Target arising
Perth[4]	117	6.2	5.3%	20% by 2012
ACT[4]	32	2.2	6.7%	20% by 2013
Major urban water utilities[5]		125	9% (Average)	
Non-major urban water utilities[5]		42	23% (Average)	

Source: Data collated from different reports on the websites mentioned below:

[1] Melbourne Water http://www.melbournewater.com.au

[2] Sydney Water, Sydney Water Annual Report 2006. http://www.sydneywater.com.au

[3] SA Water, from the document titled "A thirst for change – water proofing Adelaide 2005-2025. A blueprint for the management, conservation and development of Adelaide's water resources to 2025. http://www.sawater.com.au

[4] Water Services Association of Australia. National performance report for major water utilities. 2005-06. https://www.wsaa.asn.au/frameset2.html

[5] Water Services Association of Australia. First national performance report for urban water utilities. Media release on 17 May 2007. https://www.wsaa.asn.au/frameset2.html

2.4 Key Drivers for Wastewater Recycling

A number of factors have driven the government/water authorities to consider and to invest in wastewater recycling. The literature review reveals the following key drivers:

1. **Limited and decreasing freshwater sources:** Freshwater is a limited resource which has increasing competing alternative uses for it. With frequent droughts and decreasing and irregular rainfall patterns over the years (see Figure 5 below), the need to look for alternate water sources has become imperative. 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).

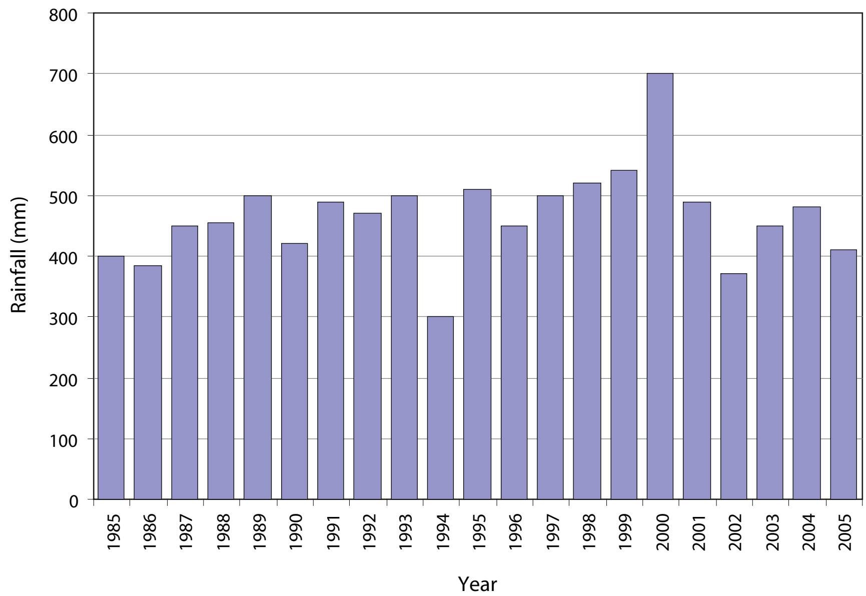


FIGURE 5. Annual rainfall – 1985 to 2005. *Source:* Bureau of Meteorology 2006

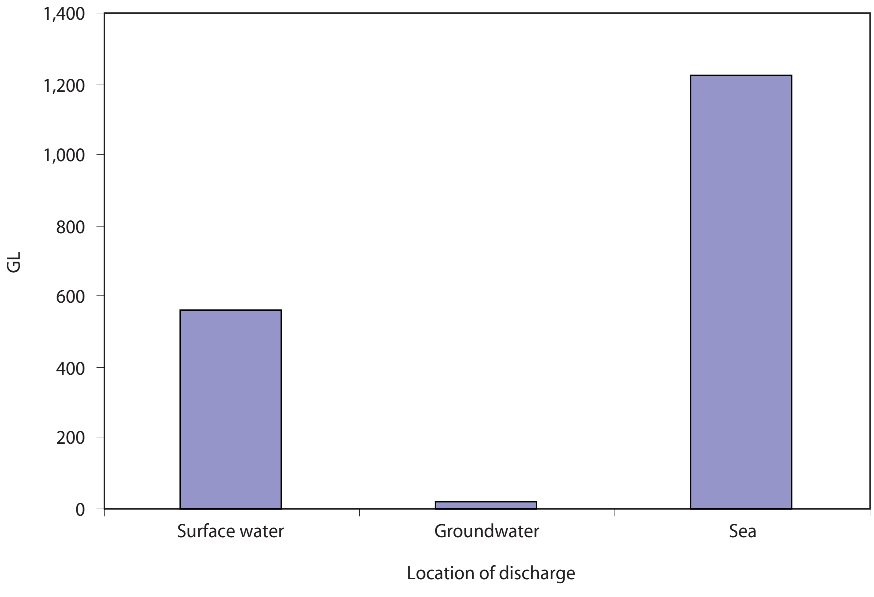


FIGURE 6. Regulated discharge from water supply industry, by receiving body, 2004-05 (Australia). *Source:* ABS 2005

2. **Environmental concerns:** Of the 1,809 GL discharged by the water supply industry (ABS 2006), 68% was discharged to the sea, 31% discharged to inland surface water, with the remaining 1% discharged to the groundwater (see Figure 6)

Although most water that is released into surface and groundwater is automatically recycled in some form or other, water released into sea may not be. This implies a loss to the society as a whole. Therefore, wastewater recycling supports the environmental cause by:

(a) Minimizing the potentially negative impact of nutrients released into the natural water bodies that come from water treatment plants;

(b) Substitution of water used in peri-urban agriculture and urban irrigation and the freeing up of water for environmental purposes;

(c) Conservation of higher quality water for suitable uses; and

(d) Satisfying the demand from the general community to have greener water strategies and water conservation.

3. **Economic reasons:** Wastewater treatment is an expensive process and cost recovery and decreasing the burden of sewerage charges on urban dwellers could be an important driver for wastewater recycling. 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.

2.5 Quality of Wastewater in Australia

Wastewater, if treated appropriately, has the potential to be recycled in a number of sectors. Recycled water can be treated to a number of different standards using different technologies depending on the quality required. In Victoria, Australia, treated wastewater is again classified into classes A, B, C and D (See Table 4) for more information on their quality and uses). Class A is the highest rating for recycled water used for non-potable supply and exceeds the guidelines recommended by the World Health Organization (Radcliffe 2004). Class A recycled water is considered safe for use in human food crops, including those eaten raw, whereas the least treated wastewater is class D, which has limited use for irrigation of woodlots and flowers. The Biological attributes of wastewater may not be relevant when this water is used in primary industries. However, the issues of salinity and mineral content of treated wastewater is of concern to most primary producers as it might significantly affect plant and soil health and over a period of time reduce the productivity of land. Each recycling standard has a number of associated risks and its use should be based on sound economic analysis that takes into account all the environmental and social externalities generated from wastewater recycling.

TABLE 4. Classes of reclaimed water and corresponding standards for biological treatment and pathogen reduction.

Water quality indicative objectives uses	*Treatment processes*	*Range of uses – uses include all lower class*
Class A • <10 *E.coli* org/100 mL • Turbidity <2 NTU • <10/5 mg/L BOD/SS • pH 6–9 • 1 mg/L Cl2 residual (or equivalent disinfection)	Tertiary and pathogenreduction to achieve: <10 *E.coli* per 100 mL; <1 helminth per liter; <1 protozoa per 50 liters; and<1 virus per 50 liters.	Urban (non-potable): with uncontrolled public access Agricultural: e.g., human food crops consumed raw Industrial: open systems with worker exposure potential
Class B • <100 *E.coli* org/100 mL • pH 6–9 • <20/30 mg/L BOD/SS	Secondary and pathogen(including helminth reductionfor cattle grazing) reduction[7]	Agricultural: e.g., dairy cattle grazing Industrial: e.g., wash-down water
Class C • <1,000 *E.coli* org/100 mL • pH 6–9 • <20/30 mg/L BOD/SS[8]	Secondary and pathogenreduction (includinghelminth reduction for cattlegrazing use schemes)	Urban (non-potable) with controlled public access Agricultural: e.g., human food crops cooked/processed, grazing/fodder for livestock Industrial: systems with no potential worker exposure
Class D • <10,000 *E.coli* org/100 mL • pH 6–9 • <20/30 mg/L BOD/SS	Secondary	Agricultural: non-food crops including instant turf, woodlots and flowers

Source: EPA 2003

2.6 Government/Institutional Role in Wastewater Recycling

Through various policy instruments and policy documents, the government implements its decisions. The various rules and regulations of the government are implemented through its various agencies at the state and federal level. Last decade has seen significant reforms in water policy that have been summarized in a number of works (McGuckian 2002; Radcliffe 2003) which have suggested reforms in water pricing, institutions, irrigation systems, water allocation and entitlement (Tisdell et al. 2002), a national framework for the implementation of property rights in water and the need for an integrated catchment-wide approach to water and land resource management (ESD 1991). With the frequent droughts in the last few years and the widening gap between the supply and demand for water, various studies have been conducted and strategies have been developed to secure water for Australia. A summary of the findings, plans and recommendations highlighted by various documents is provided below:

- A State of Environment report of the Department of Environment and Heritage (1996) noted that sewage disposal was inadequate and the state regulatory bodies have emphasized the need to reduce nutrients to coastal environments (Radcliffe 2003).

- A series of guidelines published under the National Water Quality Management Strategy including Guidelines for Sewerage Systems and Effluent Management (ANZECC, ARMCANZ and NHMRC 2000a, b).

- Establishment of a National Water Policy including State and local targets, with time frames for effluent use, storm water retention and pollution removal, decentralized small-scale sewage treatment and reduced effluent discharge to oceans were recommended by a senate inquiry into Australia's management of urban water (Allison et al. 2002).

- In 2004, the Victorian government released a Cabinet White Paper with the specific aim of securing the supply and use of the State's water assets over the next 50 years which includes recycled water in Victoria's water allocation framework.

The role of various government institutions related to wastewater recycling is as follows:

1. **Environmental Protection Agency (EPA):** EPA is responsible for the developing and applying of best practice management guidelines for reclaimed water irrigation (EPA 2003). The draft guidelines are developed on a systems view of the irrigation process, incorporating a risk management approach. Performance outcomes for thirteen critical components of a recycled water irrigation system covering the topics of reclaimed water, environmental, social and economical factors are provided by the guidelines. For each factor, the guidelines list desired results, probable associated risks, appropriate practices and monitoring required (Kularatne et al. 2005: 15). Every reuse scheme requires the approval of the Department of Human Services and the EPA and must show that appropriate safeguards are in place before the reuse scheme is commissioned to ensure that the water quality offered to the growers is 'fit-for-purpose'. It is the role of the EPA to ensure that these guidelines are effectively implemented. This is achieved by undertaking audits of selected reuse schemes (random or priority site basis) and maintaining a database of all schemes throughout Victoria. The EPA is also responsible for auditing and reviewing the effectiveness of these guidelines. Reviews will occur from time to time reflecting up-to-date developments on the use and management of reclaimed water in Australia and overseas. For complete guidelines for Victoria visit *http://www.epa.vic.gov.au/water/reuse/default.asp*

2. **Department of Human Services (DHS):** DHS is responsible for ensuring that Class A reuse schemes do not pose a risk to public health. Given the potential lack of exposure 'barriers' in Class A schemes DHS involvement is to ensure that treatment plants produce Class A reclaimed water. Unless Class A reclaimed water uses involve variations from this guideline, the DHS is not required to endorse the aspects of an EIP dealing with end-use. As such, the treatment plant commissioning and water quality verification aspects of Class A schemes must be referred to the DHS for endorsement, prior to submission to the EPA, Victoria, for sign-off.

3. **Council/local government:** Councils control development zoning, minimum subdivision size, infrastructure size, infrastructure provision, and land use controls. Depending upon the selected application of the recycled water, a large recycled water development requires approval from the council for setting up/construction of the required infrastructure for recycling. Developments like farm forestry, aquaculture and structures for cut flowers require development consent from the council.

2.7 Social Aspects of Wastewater Recycling

1. Yuck factor

The "yuck" factor or disgust in psychological terms is defined as the emotional discomfort generated from close contact with certain unpleasant stimuli (Angyal 1941). The general community has openly acknowledged that there is a psychological barrier to using recycled water on many occasions (Melbourne Water 1998; Kaercher et al. 2003). According to the law of contagion (Rozin and Fallon 1987) any neutral object through brief contact with another object (e.g., hair in soup) may acquire disgusting properties. Therefore, regardless of the highest treatment of the wastewater, people may still perceive the water to be disgusting because the water has been in contact with human wastes which results in disgusting stimuli. Also, Frewer et al. (1998) stated that people use their moral and social values known as outrage factors to evaluate situations. Based on these outrage factors, Po et al. (2004) suggests that people may perceive wastewater too risky to use because (1) the use of this water source is not natural; (2) it may be harmful to people; (3) there might be unknown future consequences; (4) their decision to recycle water may be irreversible; and (5) that the quality and safety of the water is not within their control.

Studies conducted by Bruvold (1988), ARCWIS (2002) and Sydney Water (1999) showed that the closer the recycled water is to human contact or ingestion, the more people are opposed to using the water. Reuse decreased substantially as the use moved from public areas to inside the home, and from toilet flushing, laundry, bathroom and kitchen uses to drinking. Introducing recycled water on low or non-human contact use and gradually moving along the contact continuum is expected to increase the acceptability of recycled water.

2. Acceptability of wastewater by the primary producers

Scarcity of water is assumed to trigger the demand for recycled water. However, according to Kularatne et al. (2005: 17) the presence or absence of water is only one dimension of the problem and wastewater recycling is influenced by a number of other factors like – the volume of water available relative to existing supply, the timing of availability, the consistency and quality of supply and the desire of suitably skilled and knowledgeable people to invest. In addition to this Kularatne et al. (2005: 19) present a number of social aspects that influence the primary producers'/landholders' decision to accept wastewater recycling which are as follows:

- Landholder's aspirations for their properties: The goals of the families of primary producers are varied and may include financial security, environmental improvement, social approval and personal ethical standards. The dynamic social setting of a region is also supposed to play an important role in the adoption of new technologies and all the "bigger decisions" by farmers (Pannell et al. 2005). Real estate prices and the increasing demand for land suited to lifestyle choices and not production will also influence landholders' aspirations for their properties.

- Landholder's capacity to change: Doyle and Johnson (2005) found that farmers with a higher risk tolerant attitude and flexibility to building farm equity may be more open to adopting new technologies for water use efficiency. According to them farmers adopt new technologies under these scenarios namely – adoption will provide measurable benefit; interventions are in place to overcome any barriers that a farmer might face; mechanisms are used to alter the operating environment so that the consequences of adoption are preferable to the consequences of non-adoption. A detailed analysis of how recycled water might change existing farm management operations and business planning might be essential to reveal the capacity for changing practices and associated resource use. While contemplating a major change in the farming system, the landholder will actively seek information. The more serious the consequences of a new practice, the stronger the need for information and confidence about the outcomes (Pannell et al. 2005). Kularatne et al. (2005: 19) conclude that farmers' decisions to change production management or practices will be based on a complex and interwoven series of contextual issues that span personal, family, economic and social goals.

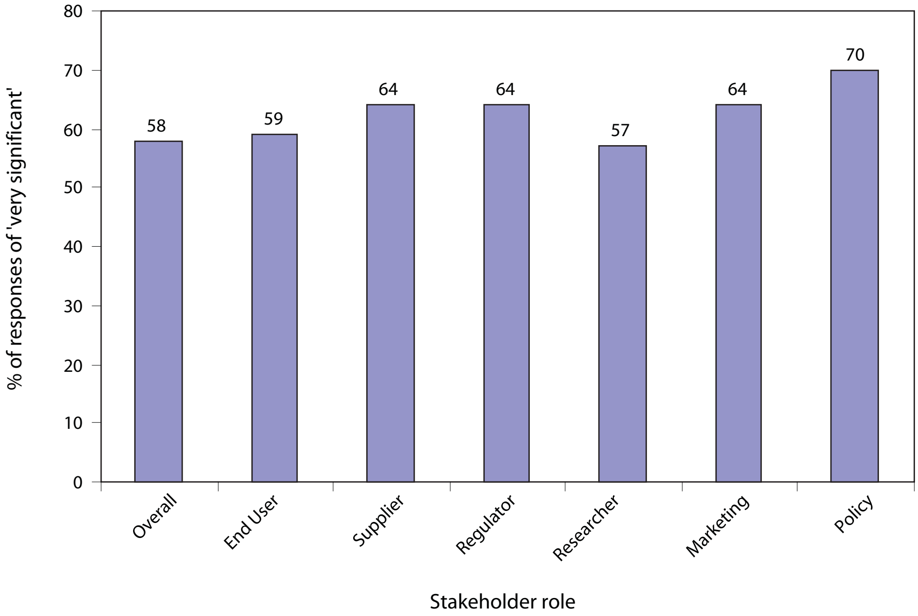
- Landholder's willingness to use recycled water: Adoption is based on subjective perception or expectations rather than on objective truth (Pannell et al. 2005). The Virginia pipeline Scheme, north of Adelaide initially faced significant customer resistance to paying the full cost of recycled water and government equity effectively subsidized those that pioneered shifts in water use. As the customer confidence in the scheme increased, the pricing structure for the water has been altered to reflect the true cost of providing the resource to the customer. Farmer's confidence in production yield and quality, income security, and contractual supply chain issues may be more important than the potential for windfall gains or high marginal returns. Incentives in the form of pricing, education and training mechanisms are important introductory measures that assist with promotion of user confidence.

- Landholder's economic considerations: The economic drivers for using recycled water and the economic impact it can make on individual farms can vary according to the scale of farm production (i.e., small versus medium and large operations). In some cases, larger the scales of operation, greater are the production benefits from new systems or technology. Whereas in some cases, it may be beneficial for small or medium scale businesses to adopt recycled water due to the lower impact of the overall on-farm infrastructure cost compared to more extensive operations. Smaller scale operations may also limit costly negative externalities. However, more research is required in this regard, since the exact on-farm economic impact of using recycled water for individual farm businesses is currently unclear.

2.8 Costs of Recycling

The absolute as well as the relative cost of supply of recycled water to the suppliers and to the end user are important components for the overall implementation and success of recycle water projects. In a research carried out by ACIL Tasman Pty Ltd. (2005) for the Australian government, 58% of respondents believe that the issue is "very significant" as an impediment to the use of recycled water, while only 13% believe it is "insignificant" (see Figure 7). The demand for recycled water use is influenced by not only cost of supply of recycled water alone but also the relative cost of alternative sources of water.

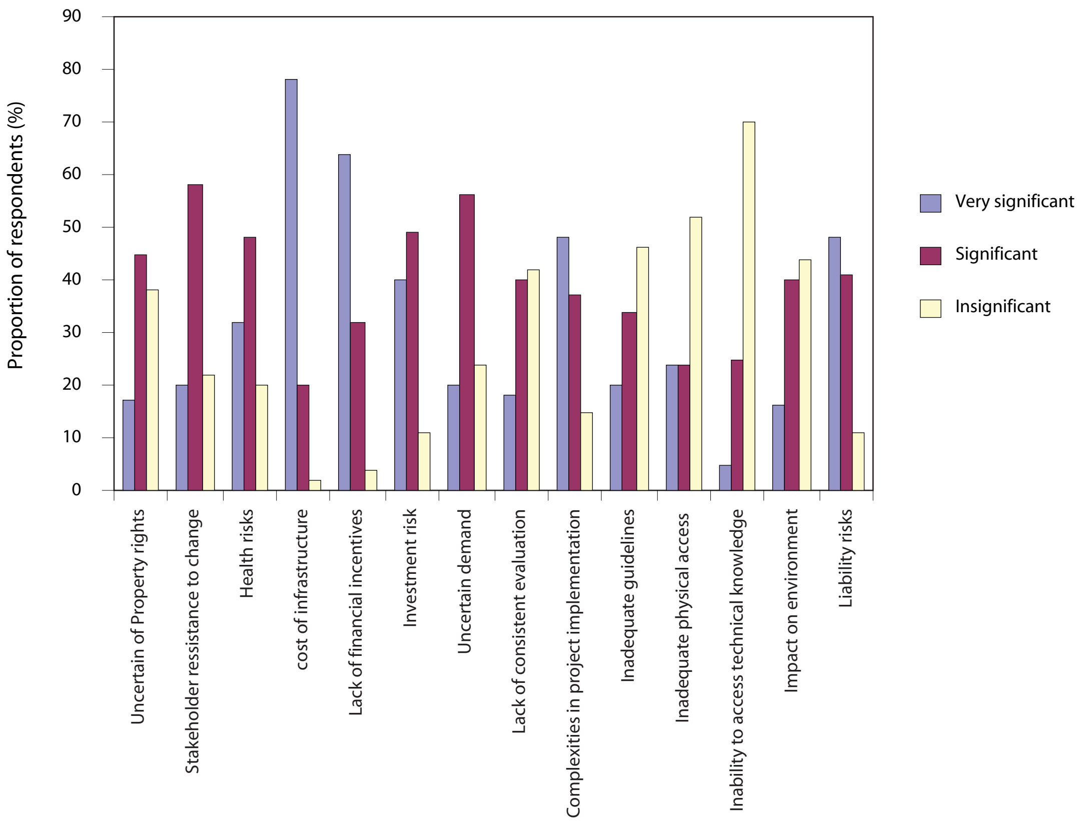
FIGURE 7. Cost relative to alternatives as an impediment to use recycled water.



Source: ACIL Tasman Pty Ltd. 2005

The ACIL Tasman Pty Ltd. (2005) study also revealed that 80% of the 45 stakeholders involved in recycled water supply ranked the cost of the infrastructure among other impediments (see Figure 8) as a very significant impediment to recycling.

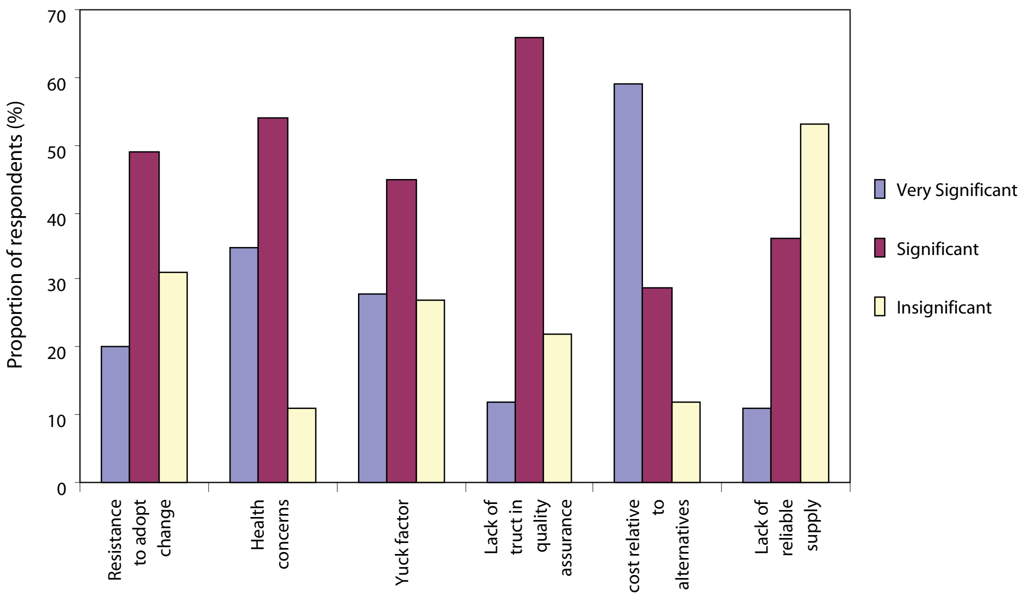
FIGURE 8. Impediments to supply – suppliers only.



Source: Reproduced from ACIL Tasman Pty Ltd. 2005
Notes: Based on a sample of 45 stakeholders involved in recycled water supply

Further, looking at the demand side, the view of stakeholders on the relative significance of various impediments is summarized in Figure 9. The most important impediment to use, as based on responses to the survey, is the cost of recycled water relative to the cost of alternative water sources. Approximately 60% of respondents identified this as a "very significant" impediment to use. Therefore, many of the wastewater supply companies had to provide recycled water at subsidized prices (see Table 5). Other impediments to use recycled water that were identified as important include health concerns over the safety of using recycled water, and a resistance amongst users to adopt change and use what is a relatively 'new' product compared to more traditional first-use water.

FIGURE 9. Impediments to use recycled water – all respondents.



Source: Reproduced from ACIL Tasman Pty Ltd. 2005
Note: Based on a sample of 101 key stakeholders in recycled water industry

TABLE 5. Comparison of the costs of some recycled water schemes with the price charged and prices of drinking water.

Location	Use of recycled water	Recycled price/kL	Real cost estimate of recycled water	Drinking water price/kL
Springfield, QLD	Residential—toilet flushing, garden	43c	$1.45	Per quarter: 90c for 100–150 kL
Rouse Hill, NSW	Residential—toilet flushing, garden	28c	$3.00-$4.00	98c
Olympic Park, NSW	Residential supply—toilet flushing, garden, laundry	83c	$1.60 (operating costs only)	98c
Mawson Lakes, SA	Residential—toilet flushing, garden watering	77c	Not available	$1.03 for >125 kL

Sources: Australian Academy of Technological Sciences and Engineering, 'Water recycling in Australia', Melbourne, 2004; D. Hatton MacDonald 'The economics of Water: Taking full account of first use, reuse and return to the environment' CSIRO Land and Water Client Report, Adelaide, 2004; A. Hurlimann, J. McKay, G. Geursen 'Pricing of drinking water vs recycled water: fair ness and satisfaction' in *Water*, March 2005, pp.30–34.

Treating wastewater to a high level, using secondary through to advanced processes, can be very energy intensive. Wastewater recovery from water with less total dissolved solids than seawater has lower energy costs for reverse osmosis.

Per kiloliter of potable water produced, the standard requirements for energy consumption are:

- 3 to 5 kilowatt hours (kWh) for reverse osmosis of seawater (Water Corporation 2005),
- 0.4 to 0.6 kWh for conventional water treatment (Swinton 2005),
- 0.7 to 1.2 kWh for brackish reverse osmosis (Swinton 2005), and
- 0.8 to 1.0 kWh for wastewater reclamation (Swinton 2005).

Thus, the type of water targeted for reclamation as well as improved environmental efficiencies are important considerations.

3. WASTEWATER USE IN INDIA

3.1 Wastewater Volumes in India

Urban areas in India generated about 5 billion liters a day (bld) of wastewater in 1947 which has increased to about 30 bld in 1997 (Winrock International India 2007). According to the Central Pollution Control Board (CPCB), 16 bld of wastewater is generated from Class-1 cities (population >100,000), and 1.6 bld from Class-2 cities (population 50,000-100,000). Of the 45,000 km length of Indian rivers, 6,000 km have a bio-oxygen demand above 3 mg/l, making the water unfit for drinking (CPCB 1998). An estimated 80% of wastewater generated by developing countries, especially China and India, is used for irrigation (Winrock International India 2007). In India, where wastewater is mainly used in agriculture, a policy framework covering the issues associated with this practice is lacking. Strauss and Blumenthal (1990) estimated that 73,000 ha were irrigated with wastewater in India. However, Buechler and Mekala (2003: 939) estimated that even just along the Musi River, that runs through Hyderabad city in Andhra Pradesh State, and the canals and tanks off this river, approximately 40,000 ha of land were irrigated with urban and industrial wastewater diluted with fresh river water especially during the monsoon season.

Untreated wastewater from domestic, hospital and industrial areas pollute rivers and other natural water bodies. More than 80% (only 4,000 Million Liters per Day [MLD] out of 17,600 MLD wastewater generated in India is treated) of wastewater generated is discharged into natural water bodies without any treatment due to lack of infrastructure and resources for treatment (Winrock International India 2007). Approximately 30,000 MLD of pollutants enter India’s rivers, of which 10,000 million liters are from industrial units alone (CPCB 1995). Farmers have customary rights to any water that flows through the river and it should be the responsibility of the irrigation and water authorities to maintain the quality of this water to ensure the sustainable use of this water. The interviews held with farmers along Musi River in Hyderabad clearly highlight that the wastewater quality is very poor and has adverse impacts on the health of farmers and reduces soil productivity over time, not to mention the high water tables and groundwater contamination in these areas. However, regulations related to water pollution in India are incomplete (Buechler and Mekala (Forthcoming)). The Water Act covers industrial effluent standards, but ignores the domestic and municipal effluents even though they constitute 90% of India’s wastewater volumes (Sawhney 2004: 26).

3.2 Wastewater Market

Pollution of both surface and groundwater sources and its associated problems, constitute one of the biggest environmental problems of India. A report by Winrock International India (2007) states that the market for adoption of advanced technologies for wastewater use arising from industries and municipal corporations accounts for the largest percentage of the total environmental market in India. A survey by the US Trade department reveals that the total market potential for water and wastewater treatment including the requirements of Municipal and Industrial sectors is estimated at US$900 million and is expected to grow at approximately 14% each year in the mid-term (Swiss Business Hub India & Heinz Habegger, Baleco AG, Thun 2004). The survey further states that industrial wastewater treatment accounts for nearly half of the total market size for treatment. The water and wastewater treatment sector also accounts for the highest environmental spending within both the public and private sectors. Considering the fact that conventional treatment techniques are extremely expensive for countries like India, there is an urgent need for alternate methods of treatment and recycling of wastewater.

3.3 Wastewater Reuse

In India, since wastewater is mainly untreated, it is used in the agricultural sector where the risks are considerably lower to using it in households or industry. From literature review and personal experience in this area, one can state that untreated and partially treated wastewater released from the major cities of India like New Delhi, Mumbai, Bangalore, Kolkata, Hyderabad, Ahmedabad, etc., is mainly used for irrigation of the following crops:

- **Cereals:** In Hyderabad, along the Musi River about 2,100 ha of land is irrigated with wastewater to cultivate paddy (Mekala 2006). In Ahmedabad and Kapur, wheat is extensively irrigated with wastewater (Winrock International India 2007).
- **Vegetables:** In New Delhi, about 12,000 farmers use treated wastewater in areas around Keshopur STP and Okhla STP to irrigate 1,700 ha of land to grow vegetables like Cucurbits, eggplant, okra, and coriander in the summers; Spinach, mustard, cauliflower, and cabbage in the winters (Winrock International India 2007). In Hyderabad, about thirteen different kinds of vegetables are grown with wastewater all year round which include spinach, malabar spinach, amaranths, gogu (Hibiscus *cannabinus*), mint, coriander, bladder dock, okra, colocasia, *soya* (Glycine max), common purslane and *chennangi* (Lagerstroemia *parviflora*).
- **Flowers:** Farmers in Kanpur grow roses and marigold with wastewater. In Hyderabad, the farmers cultivating Jasmine through wastewater generates a lot of employment. The jasmine plantation produces flowers for 8-9 months per year and a 118 farmers can earn approximately Rs. 15,000 to Rs. 20,000 per ha for an 8-9 month flowering season (Buechler et al. 2002).
- **Avenue trees and parks**: In Hyderabad, secondary treated wastewater is used to irrigate public parks and avenue trees.
- **Fodder crops:** In Hyderabad, along the Musi River about 10,000 ha of land is irrigated with wastewater to cultivate para grass, a kind of fodder grass (Mekala 2006).

- **Aquaculture:** The East Calcutta sewage fisheries are the largest single wastewater use system in aquaculture in the world (Pescod 1992). The wetland ecosystem of Kolkata supports 100,000 direct stakeholders and 5,100 ha of cultivation. Annually, it provides direct employment for about 70,000 people, produces 128,000 quintals of paddy, 69,000 quintals of fish and 7.3 quintals of vegetables (Chattopadhyay 2004).

- **Agroforestry:** In the villages near Hubli-Dharwad in Karnataka, the main wastewater-irrigated agroforestry land uses are orchards and agrosilviculture which consists of spatially mixed tree–crop combinations (Bradford et al. 2003). The two most important tree species are sapota and guava, and other common species are coconut, mango, arecanut and teak. Species found on farm boundaries include neem, tamarind, coconut and teak. Other less common species are banana, ramphal, curry leaf, pomegranate, lemon, galimara and mulberry. In agrosilviculture, field crops grown include irrigated groundnut in the dry season and sorghum in the *kharif* season. Many adaptations of the agrosilviculture system were observed. Farmers in Budarsingi and Katnur villages also identified vigorous weed growth as the main constraint to agroforestry.

Treated wastewater can be used for various industrial uses such as in cooling towers, boilers, washing the work spaces, etc., if adequately treated, depending upon its availability and location. Chennai is a pioneer in such wastewater reuse in India (YUVA, Mumbai. 2005).

3.4 Implications of Wastewater Reuse

There are both positive and negative implications of wastewater reuse. The positive implications include: employment generation, food security for urban and peri-urban poor farmers, reliable supply of irrigation water and the recycling of nutrients in wastewater. Since wastewater is available all year round, the urban poor farmers and migrant laborers are assured of employment throughout the year. In the peri-urban areas along Musi, Hyderabad, it was found that wastewater-irrigated paddy contributes almost 43% of household food consumption (Buechler and Mekala 2005). The high nutrient content of the wastewater helps farmers save on the fertilizer costs and its reliable supply helps increase the cropping intensity. Wastewater can also have a positive or negative impact on the property values. In Haroonabad, in Pakistan, the wastewater-irrigated land has a higher value than the canal-irrigated land (Hussain et al. 2001).

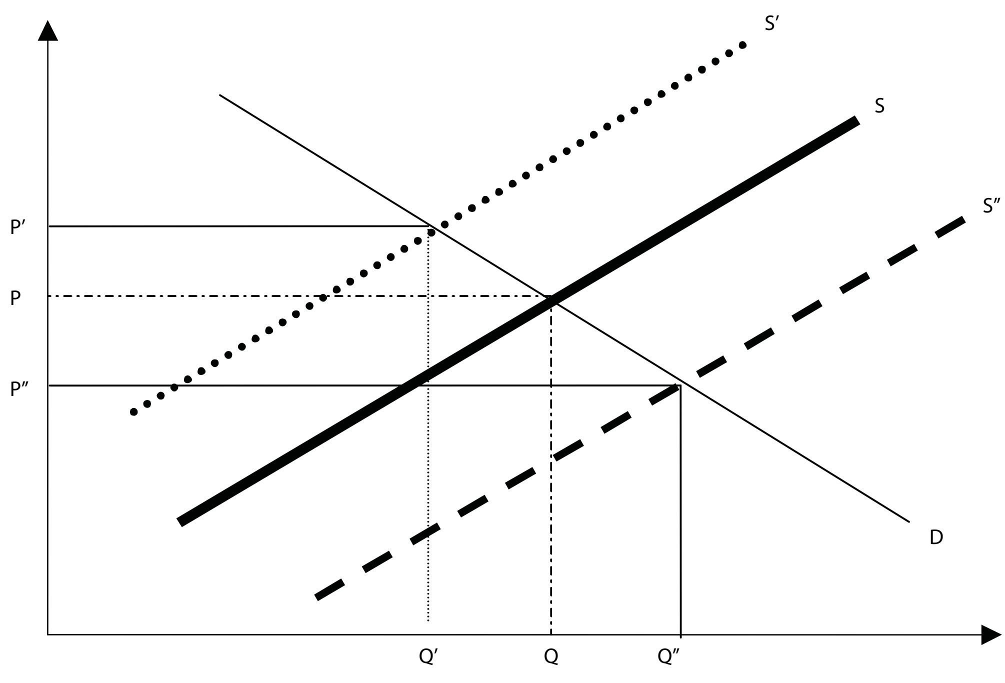
On the other hand, because of the partial or no treatment of wastewater, it endangers the very livelihoods it generates over the long term. Long-term use of wastewater for irrigation increases soil salinity, accumulation of heavy metals in the soil, and finally breakdown of the soil structure. This in turn leads to restriction on crop choice and reduction in yields over the long run. Along the Musi River near Hyderabad, where wastewater is drawn from the river for irrigation, the paddy (rice) production has reduced by 40-50%. Ample evidences are available which show that the groundwater in all wastewater irrigated areas has high salt levels and is unfit for drinking. Further, high groundwater tables and waterlogging are also common features of these areas. Wastewater contains a number of pathogens of which human parasites such as protozoa and helminth eggs are of special significance which can cause diseases in user communities and consumers. Further, wastewater containing a high level of nutrients may cause eutrophication and cause imbalances in the ecology of the water bodies, it is released into.

In addition, a number of social concerns like impaired quality of life, loss of property value, food safety, health and welfare and sustainability of land use are associated with wastewater use (Hussain et al. 2001).

3.5 Water Markets and Potential of Wastewater

The price of water, just as other commodities, can be determined using the demand and supply curves. Figure 10 shows the supply curve (S) and demand curve (D) for water and their point of intersection gives the quantity of water (Q) that should be supplied at price P under normal market conditions with no government interventions. Whenever, there is a scarcity of water due to higher demand or lower rainfall or when the government decides to conserve water for future use, it needs to reduce the present supply (from Q to Q'). Accordingly, P' gives the scarcity price of water. To reduce the gap between supply and demand, water boards and communities are exploring a number of alternate water options to complement the existing urban water supplies which include – wastewater recycling, rainwater harvesting, storm water recycling, exploring new groundwater sources, diverting agriculture water to cities and the construction of new dams. If any or a combination of these sources are tapped, the supply curve will move towards the right (S") and the urban people can pay a lesser price, P". Wastewater if treated to appropriate levels has a huge potential to complement the existing water sources and bring down the price from P' to P". However, the costs of treatment need to be deducted from the benefits to realize the net profit from recycling.

FIGURE 10. Water markets: demand and supply curves.



3.6 Urban water pricing

Urban water pricing has the following components:

1. Cost of water supply: In most OECD (Organisation for Economic Co-operation and Development) countries and in the USA water pricing is based on average cost pricing or marginal cost pricing. The consumers are charged at the rate of per kiloliter of water consumed. This rate varies depending on the pricing structure in each city.

2. Cost of maintenance of sewerage services: In most cities around the world, the water boards are also responsible for maintaining the sewerage system and consumers are charged for this service. In Hyderabad, 35% of water supply charge is charged as sewerage cess. In New Delhi, 50% of water supply charge is charged as sewerage cess.

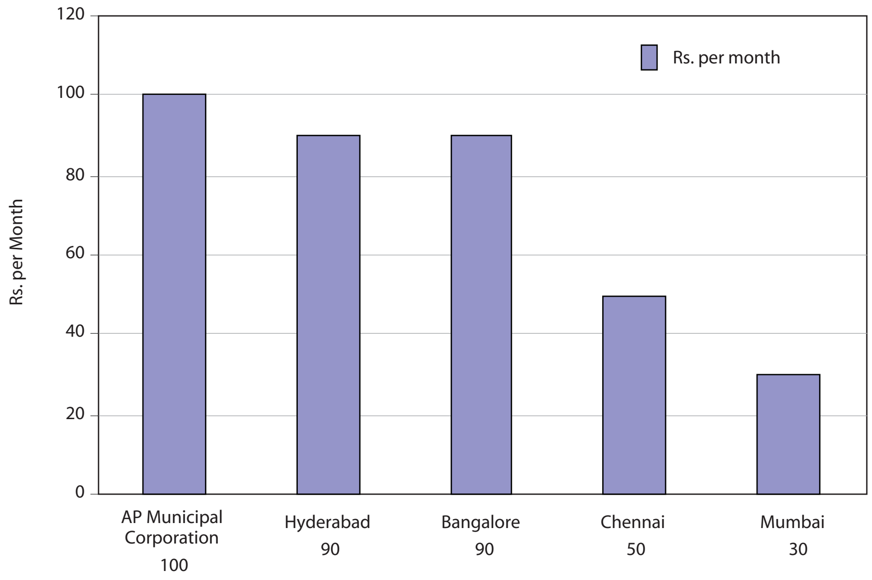
3. Cost of treatment of sewage water or wastewater discharged by households and industries: Urban consumers in none of the Indian cities are charged for treatment of sewage. However, most of the developed countries have introduced the "polluter pays principle" for the amount of water pollution load discharged by companies and wastewater treatment charges are fully recovered from the urban consumers as well.

4. Service charge: In India, in most cities, a minimum service charge is included in the water bill.

In India water is a highly subsidized commodity leading to market inefficiencies and hence inefficient use of the already scarce resource. The water subsidy in the urban areas has important consequences for the poor and the environment. The urban water authorities, usually known as Water Supply and Sewerage Boards, are responsible for the city's water supply and sewerage services. Since urban water is subsidized, these institutions constantly incur losses and have no funds to invest in repairs and maintenance of existing water supply infrastructure, wastewater treatment and expansion of their services. Another important consequence of urban water subsidies is that the urban water consumers and polluters are not charged for sewerage treatment and hence in most developing countries, only 20-30% of wastewater is treated to secondary level.

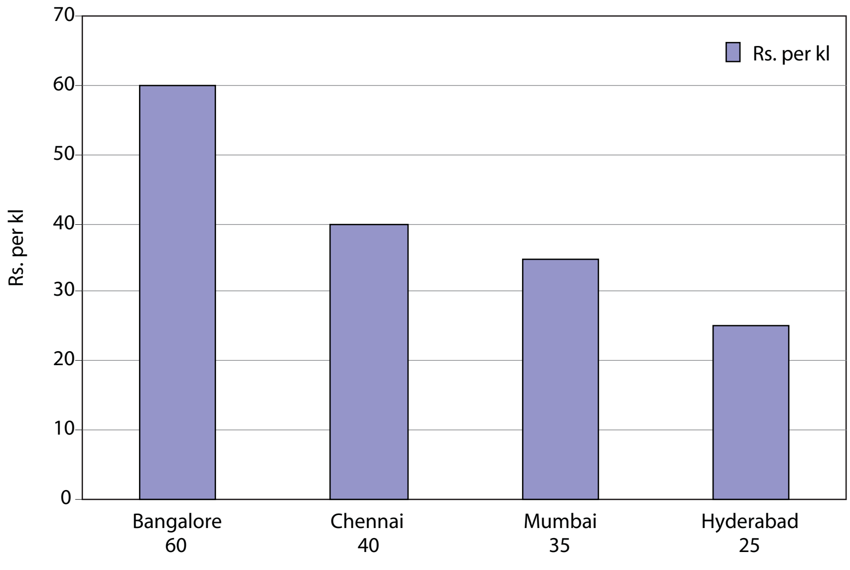
Figure 11 shows the average price charged by water boards to urban domestic consumers in the major cities of India – Delhi, Kolkata, Bangalore, Chennai and Hyderabad. The average cost incurred by the water boards to supply water in most metropolitan cities ranges from Rs. 10 to 35 per kl and the price charged to urban domestic consumers ranges from Rs. 6 to 36 per kl depending on the volume consumed. The price for non-domestic consumers varies from Rs. 20-100 per kl depending on the volume consumed and the type of industry (see Figure 12).

FIGURE 11. Average price charged by water boards to urban domestic consumers.



Source: http://www.cnet.at/hywamis/Bilder2/Presentation%20HMWSSB.pdf

FIGURE 12. Average price charged by water boards to urban non-domestic consumers.



Source: http://www.cnet.at/hywamis/Bilder2/Presentation%20HMWSSB.pdf

In India urban consumers pay less for the municipal water than the actual cost of supply incurred by the water boards. Consumer utility subsidies are a common feature of water services around the world. The majority of water utilities charge tariffs, which are substantially below the levels required for full cost recovery. Nearly 40% of utilities worldwide do not even cover operating and maintenance costs (Jellinek et al. 2006). Average water tariffs in low-income countries stand at about a tenth of the level applied in high-income countries. Subsidies on water utilities can be a significant drain on the public treasury. In India, drinking water subsidies have been estimated at 0.5% of the gross domestic product (GDP) (Jellinek et al. 2006). Implicit subsidization due to generalized underpricing of the service, asset mining and not charging the urban consumer for the treatment of the sewage/ wastewater are the main causes of the drain on the public treasury. Utility subsidies are promoted to make the services affordable for the poor and to expand coverage. However, according to a study released during the 4th World Water Forum (March 2006) held in Mexico City, this is not true. On the contrary, according to Jamal Saghir (Director, Energy, Transport and Water Department, World Bank), poor households capture only half as much of the value of the subsidy as they would if the subsidies were distributed randomly across the entire population and many poor households are excluded from subsidy programs altogether because they are not connected to the network.

However, contrary to the above argument, a field study conducted in Hyderabad, India by Raghavendra (2006) suggests that while ‘stated’ tariffs are low, households actually pay far more than in other regions of the world due to – poor measurement of domestic water consumption and institutional indifference towards improving the quality of service. The study further states that improvement in the quality of the services and improvement in the household’s perception of water services is essential before any increase in the water tariffs can take place to ensure full cost recovery.

In most western countries, the urban households are charged for the amount of water consumed and the amount of sewage disposed. Box 1 shows a water bill of an urban household in Melbourne, Australia as an example. The bill clearly shows that, the households are charged 81 cents per kiloliter of water supplied and AUD 1.05 per kiloliters of sewage water disposed. The water bill in Hyderabad [see Box 1] shows that INR 6 per kiloliters is paid for water supply and 35% of the water supply charges is charged as sewerage cess. However, the bill also clearly shows that no money is charged for sewage disposal or treatment. This is one of the important factors contributing to lack of funds and non-treatment of wastewater. This ultimately leads to the pollution of rivers, lakes, groundwater and soil. It also has a number of ill effects on human health, especially for those farmers who use untreated wastewater for irrigation.

Box 1. Water Bills from Melbourne, Australia and Hyderabad, India.

Water bill from Melbourne, Australia

Account Details

Water Usage from 22/03/2007 to 21/06/2007.

Meter Number	Current Reading		Last Reading		Usage
MAK053810	1,600kL	-	1,564kL	=	36kL

In 91 days you used 36.000 kilolitres, equalling 396 litres per day.
One kilolitre (kL) equals 1,000 litres.

Usage*			Price $/kL		Amount
BLOCK 1	36.000	x	0.8184	=	$29.46

*Rising block tariffs are adjusted according to the days in your meter reading period, and applied on a daily basis.

Sewage Disposal from 22/03/2007 to 21/06/2007.
For the disposal and treatment of sewage from your property. It is based on your water usage and adjusted for seasonal variations.

Usage		Seasonal Factor		Seasonal Volume		Discharge Factor		Sewage Volume
36.000kL	x	0.8700	=	31.319	x	0.900	=	28.187kL

Sewage Volume		Price $/kL		Amount
28.187	x	1.0584	=	$29.83

Water bill from Hyderabad, India

Hyderabad Metropolitan Water Supply and Sewerage Board
Khairatabad, Hyderabad - 500004

DEMAND NOTICE
Call 155313 for any complaints

CAN	BILLING MODE	BILL NUMBER	BILL DATE	CATEGORY	FROM MONTH	UPTO MONTH	NUM OF MTHS
613480828	METERED	2006616732	21-05-2007	DOMESTIC	APR 2007	APR 2007	1

To
M.Narsimha
11-4-259/1
Chilkalguda,
Chilkalguda
SECUNDERABAD 500 061

Charges	Rs. Ps
Water Cess	90.00
Sewerage Cess	31.50
Service Charges	5.00
Total	**126.50**

METER READINGS:

CONNECTION DETAILS	METER COND	PIPE SIZE	PREVIOUS READING Date	PREVIOUS READING Reading	CURRENT READING Date	CURRENT READING Reading	UN IT	KILO LITRES
613480828		0.50	04-04-2007	165,000	21-05-2007	177,000		12

Payment At Counter
eSeva/APOnline/HMWSSB

Last Date for Payment
05-06-2007

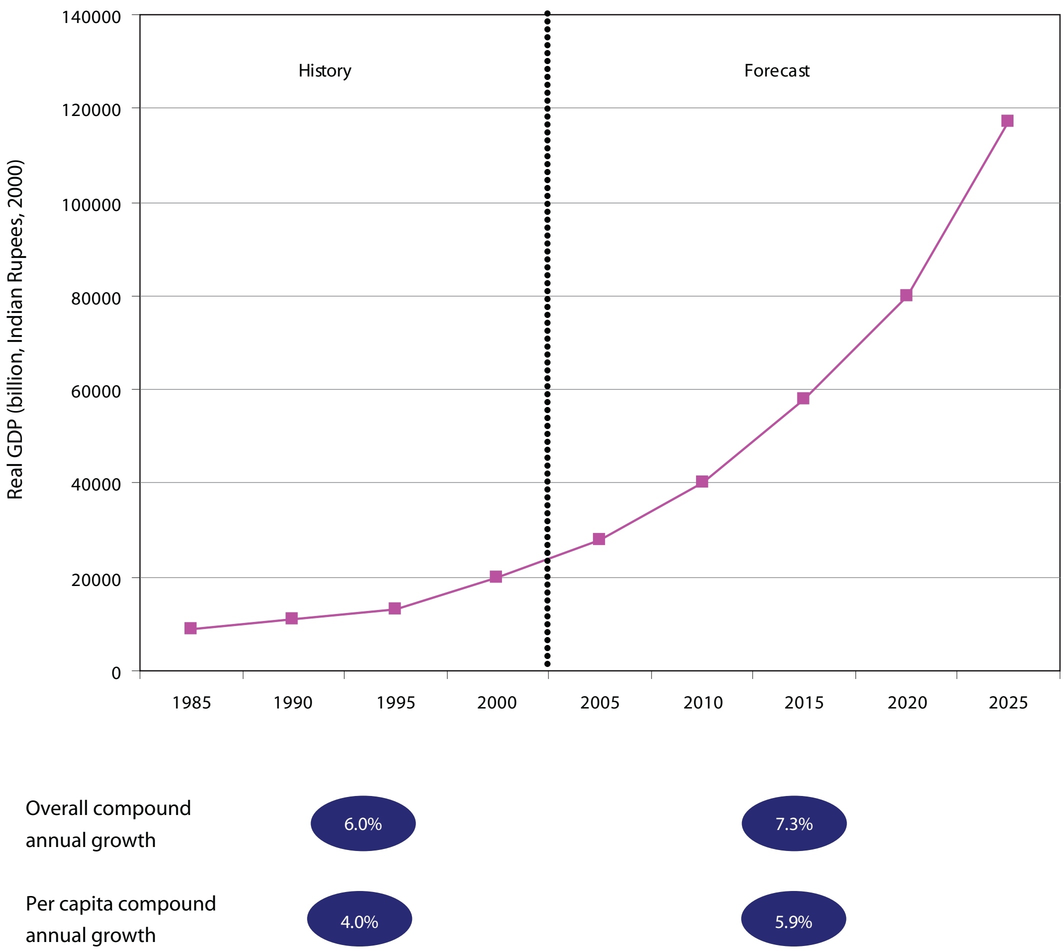
SEETHAPALMANDI SECTION
O&M DIVISION No. 7, HMWSSB

Tariff w.e.f Jan 2007 by Board's Procedings No.121 dt.14-2-2006 published in APExt. Gztt. No.429
MthlyMin:Rs.90,270,600,1500,3200 for WSPipeSizes 15mm,20mm,25mm,40mm,50mm&above OR Rs.90xflats
Tariff upto 15KLPM : Rs.6/KL;16-30 KLPM(Rs.8/KL);31-50 KLPM(Rs.15/KL);51-100KLPM(Rs.20/KL);101-200KLPM(Rs.25/KL);Abov.200KLPM(Rs.3[illegible]/KL)

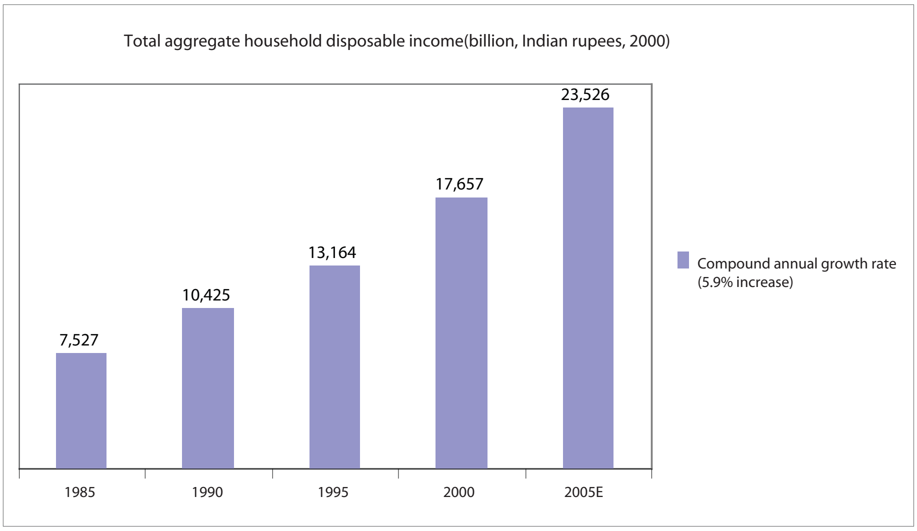
3.7 Should Urban Consumers Pay More for Water Supply and Sewerage?

Following a series of reforms beginning in the early 1990s, the GDP of India has shown a compound annual growth rate of 5.8% from 1995-2000, which increased to 6.8% from 2000–2005 (see Figure 13). India's GDP grew by 9.0% in 2005 making India the 16th-largest economy in the world in 1990 to the 13th-largest in 2005, surpassing countries such as Australia and the Netherlands (Government of India. 2006).

FIGURE 13. Compound annual growth rate of India (forecast assuming 7.3% compound annual GDP growth).



As India's economy has grown, so too has the spending power of its citizens. Real average household income in India has roughly doubled over the past two decades. Along with rising incomes have come greater consumption and the emergence of India's much-discussed "new middle class" (Shukla et al. 2004). Income growth will be fastest in urban areas where real average household incomes will rise from 166,922 Indian rupees (2007) to 513,042 Indian rupees by 2025, an annual increase of 5.8% (Ablett et al. 2007). Overall, Indian incomes have experienced a healthy growth over the past two decades. India's real aggregate disposable income has grown from 7,527 billion Indian rupees ($1,165 billion) in 1985 to 23,526 Indian rupees ($515 billion) in 2005—a compound annual growth rate of 5.9%. India's fast-growing population has meant that, on a per-household basis, real disposable income growth has been less rapid though still moderately strong, rising from 56,470 Indian rupees ($1,236) in 1985 to 113,744 Indian rupees ($2,489) in 2005—a compound annual growth rate of 3.6% (see Figure 14 below).



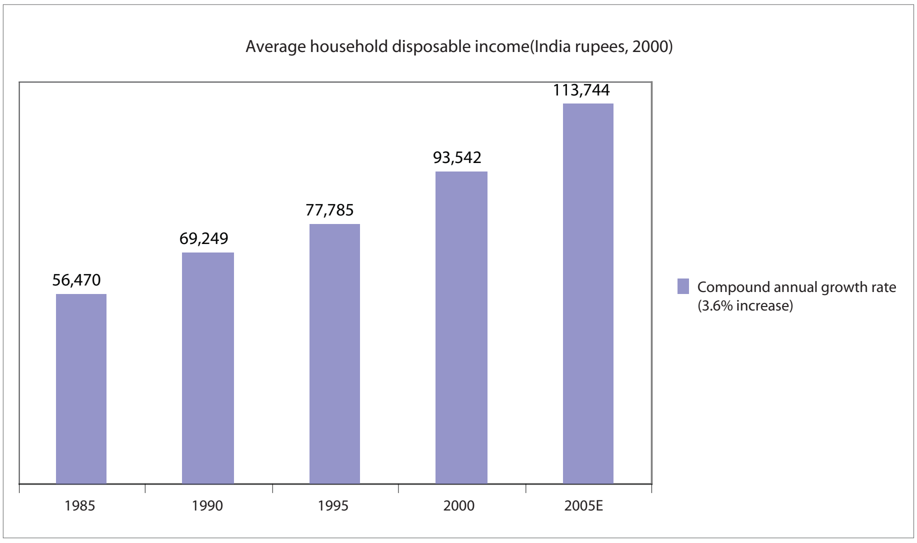


FIGURE 14. Growing incomes in the past two decades. *Source:* Graph reproduced from National Accounts Statistics: MGI India Consumer Model, v1.0

With the increase in disposable income of households, there are more and more shopping malls opening up in every corner of the metro cities to tap a major chunk of this disposable income of the new urban middle class. Also, with increasing income and education levels has come a new awareness towards the environment and the need to protect it. It is common knowledge that most rivers in India are polluted due to the disposal of untreated industrial effluents and domestic sewage. With a booming economy and increasing disposal income, there is an urgent need to introduce a new cost head in the urban water bills and introduce the "polluter pays" principal for urban water consumers. The new cost head will contribute to sewage treatment before it enters our rivers and pollutes it. A contingent valuation test can be done to test the urban consumers' willingness to pay towards wastewater treatment and maintenance of the water quality in the rivers.

4. CONCLUSIONS

Wastewater use in agriculture has been a common phenomenon in a number of water scarce developing countries for more than a century now. It has been and is still supporting the livelihoods of a number of urban and peri-urban farmers. However, with the growing population the volumes of urban wastewater have dramatically increased. The problem is further complicated with increased contamination of wastewater with new chemicals (in shampoos, soaps, etc.), with changing lifestyles of people and the addition of industrial effluents. The environmental and health related problems of the use of untreated wastewater has become prominent. There is an urgent need to address these problems before this untreated wastewater completely pollutes all the rivers/natural water bodies. Most of the developed countries have been able tackle this problem by appropriate treatment of wastewater and safe disposal with minimum environmental and health impacts. Time and again, developing countries have tried to adopt similar water treatment technologies from the western world and have failed. There are both social and economic reasons for this failure. It is very important to understand the social and economic context of a society/community/city before a technology is implemented. The different social economic aspects to be considered are – perceptions of people regarding water, education levels, awareness towards the environment and the willingness and ability to pay to protect their environment. In addition to this, the political will and institutional support are essential to make wastewater a safe asset for people in developing countries. In a number of water scarce developed countries like USA, UK, Germany and Australia, wastewater recycling is gaining importance. But they are also facing different kinds of social and economic problems (detailed in the above sections). Developed countries can benefit from the various soil, water, crop quality data of wastewater irrigated areas and wastewater use experiences of farmers in developing countries and can set their own quality standards. With issues of climate change, increases in urban population and increased demand for water from competing sectors, wastewater recycling is becoming an important strategy to complement the existing water resources for both developing and developed countries and there are lessons, experiences, data and technology which can be shared for mutual benefit.

ANNEX 1. WASTEWATER RECYCLING PROJECTS IN AUSTRALIA

Agriculture\horticulture	Industry	Household	Urban\recreation
Queensland • A number of proposals for recycling water from the coastal areas to inland agricultural users have been investigated in recent years.– One project proposed the recycling of all of Brisbane's wastewater to vegetable growers in the Lockyer Valley and cotton and cereal growers in the Darling Downs. **South Australia** South Australia's Virginia Irrigation scheme is currently the largest recycled water scheme in the Southern Hemisphere supplying 6,000 ha of irrigated crops with up to 110 ml/day of Class A water. –This public/private partnership filters effluent from Adelaide's Bolivar treatment plant and distributes it via a network of over 100 km of pipelines throughout the Northern Adelaide plains. –Aquifer Storage and Recovery has been pioneered on this project along with salinity management options (Martyn et al. 2005).Further south the privately funded Willunga Basin scheme utilizes effluent from the Christies Beach Willunga Wastewater Treatment Plant (WWTP) for the irrigation of vineyards in the McLaren Vale region. **Tasmania** • Despite the relatively high rainfall experienced in Tasmania, the use of recycled water from treatment plants discharging to waterways is increasing. Projects at Brighton and the Coal River Valley in the drier southern areas of the State will utilize effluent from urban plants for irrigated horticulture, viticulture and turf growing. **Victoria** • In Victoria the Eastern Irrigation scheme supplies 5 GL of Class A water per year to 50 agricultural and horticultural customers east of Melbourne's Eastern Treatment Plant. Effluent from the plant is further treated in a privately operated 30 ml/d ultrafiltration recycled water plant (Davey et al. 2005). • Effluent from the Western	**Queensland** In Queensland, effluent from Brisbane's Luggage Point WWTP is used for industrial purposes following further treatment in a dual micro-filtration process.–Another project investigation involved the recycling of water from Toowoomba's Wetalla Sewage Treatment Plant (STP) to the Millmerran power station **New South Wales** • Industrial reuse includes the Water Reclamation Plant supplying recycled water to the Eraring Power Station on the NSW central coast. • Investigations are underway for a supply to the steel industry in the Wollongong area. • Regional and country councils in NSW are also making a significant contribution to recycling including the extensive system being developed in the Shoalhaven area. **Western Australia** • In Western Australia, the Kwinana Water Reclamation Plant located in the industrial belt south of Perth utilizes dual membrane technology to recycle 6 GL/year of water from the nearby Woodman Point WWTP to large water using industrial customers. The treatment plant, the largest of its kind in Australia, will also process industrial waste with excess effluent being discharged to the ocean at a more sustainable location (Walker 2003). • The substitution of recycled water for potable water, currently used by industry, will make a significant contribution to preserving Perth's drinking water resources.	**Queensland** • The Springfield residential development between Brisbane and Ipswich was one of the early dual pipe water recycling projects commenced in the State and will serve an ultimate population of 60,000 people (AATSE 2004). • Gold Coast Water has developed an ambitious water resources and water recycling initiative known as the Pimpama-Coomera Water Future Project (Cox 2004).– This project will ultimately serve 150,000 additional residential populations with integrated dual pipe reticulation systems and smart sewers which could reduce the importation of drinking water to the area by up to 85%. **New South Wales** • New South Wales pioneered large-scale dual pipe residential use of recycled water with the Rouse Hill project, currently serving in excess of 12,000 properties. Water recycling and reuse of storm water are both practiced on the Homebush Bay facilities developed in conjunction with the Sydney Olympic Games (AATSE 2004). • The New South Wales Government is currently investigating significant use of recycled water in the new development areas of Southwest and Northwest Sydney as a part of its Metropolitan Strategy (DIPNR 2004).	**Western Australia** Effluent from Perth's Subiaco WWTP is being utilized for the irrigation of community parks, gardens and golf courses. **Australian Capital Territory** • ACTEW AGL has initiated a number of recycled water schemes utilizing high quality effluent from the STPs serving Canberra (AATSE 2004). • Tertiary treated effluent from Australia's largest inland treatment plant at Lower Molonglo provides water from a range of users including golf courses and vineyards with excess flows discharged as an environmental flow to the river system (AATSE 2004). **Northern Territory** • In the Northern Territory a number of water recycling projects have been developed utilizing effluent from Darwin's treatment plants for golf course irrigation and other uses. • Similar opportunities have been developed in Alice Springs where sports grounds and open spaces are utilizing "fit for purpose" alternatives to drinking water.

(continued)

ANNEX 1. WASTEWATER RECYCLING PROJECTS IN AUSTRALIA (continued)

Agriculture / horticulture	Industry	Household	Urban\recreation
Treatment Plant is disinfected with UV and chlorinated before being pumped at 80 ml/d to the supply system serving vegetable growers in the Werribee Irrigation District. **Australian Capital Territory** The Southwell Park recycled water treatment plant pioneered Australian treatment technology in a sewer mining application providing high quality water for irrigation purposes.	**Victoria** • The Eastern Pipeline Scheme, currently under investigation will supply large quantities of water for power station use in the Latrobe Valley, in conjunction with the Gippsland Water Factory project.	**Victoria** • The Aurora residential development in Melbourne's northern growth corridor will supply 8,500 lots with recycled water via a dual pipe system from an on-site treatment plant (Nadebaum et al. 2004).	

Source: If not stated otherwise the source for this information is ACIL Tasman Pty Ltd. 2005.

International Water Recycling Experiences

Agriculture / horticulture	Industry	Portable/drinking	Environment
Middle East • The Middle East is one of the world's most water-stressed regions with deteriorating quality and dwindling water supplies. • Not surprisingly, technology rich countries such as Israel have spent considerable resources on maximizing the recycling of wastewater, particularly for agricultural purposes. • Water recycling is believed to be in excess of 70%. • This trend will continue with the political imperative of increasing self-sufficiency of water resources, in which recycled water plays an important role. **Europe** • There are currently more than 200 water reuse projects operating in Europe, the majority of which operate in the coastline and islands of the semi-arid Southern regions. • In Southern Europe reclaimed water is used predominantly for agricultural purposes, while in Northern Europe it is used predominantly for urban, environmental and industrial applications. • In recognition of the need for sustainable water management processes, the European Union adopted the Water Framework Directive (WFD) in 2000. The directive is a long-term strategy, focusing on the promotion of an integrated approach to water resources management.	**Singapore** • Much more recently the NEWater project in Singapore has received a lot of international attention. • Effluent from five WWTPs is treated to potable quality to supplement the other sources of water supply to the country. • A small proportion of the water is actually consumed for drinking (1 – 2.5%) with the majority used in high quality industrial processes. • A feature of this project is the high international profile it has received and the high rate of acceptance by Singaporeans, as a result of the comprehensive community consultation and evaluation programs adopted. • A tour of the impressive NEWater Visitor Centre is becoming a common place for representatives of the Australasian and international water industry (Porter 2005).	**Africa** • In Namibia, the residents of the capital, Windhoek, were the first to experiment with the recycling of water for potable use in 1969. • The treatment processes have been progressively improved over the years and this source of drinking water still plays an important role in supplementing limited surface and groundwater supplies in this low rainfall area of Africa (AATSE 2004).	**California** • California, with its similar climate to Australia, is at the forefront of water recycling in the Americas. • The Orange County Water and Sanitation Districts were responsible for Water Factory 21 developed in 1976 as one of the first plants to produce recycled water. • Faced with reducing surface water resources and the need to protect groundwater aquifer from saltwater intrusions; the Groundwater Replenishment System is being developed to replace the original water factory with a much larger treatment facility, constructed in stages to an ultimate capacity of 265 ml/d (Chalmers et al. 2002). • The system utilizes "state-of-the-art" treatment processes to treat wastewater for pumping to groundwater spreading basins and seawater intrusion barrier injection wells.

Source: If not stated otherwise the source for this information is ACIL Tasman Pty Ltd. 2005.

REFERENCES

AATSE (Australian Academy of Technological Sciences and Engineering). 2004. *Water Recycling in Australia.* Study Director and Author: Dr. John Radcliffe, Victoria.

Ablett, J.; Baijal, A.; Beinhocker, E.; Bose, A.; Farrell, D.; Gersch, U.; Greenberg, E.; Gupta, S.; Gupta, S. 2007. The 'Bird of Gold': The Rise of India's Consumer Market. May 2007 Report. McKinsey Global Institute [MGI].

ABS. 2005. Annual Report 2005-06. *http://www.ausstats.abs.gov.au/ausstats/subscriber.nsf/0/0407DA584588E138CA25720300182FBA/$File/10010_2005-06.pdf*

ABS (Australian Bureau of Statistics). 2006. *Water Account Australia. Report no. 4610.0.* Latest issue released 11.30 am (Canberra Time) 28 November 2006. Australian Bureau of Statistics. Commonwealth of Australia *http://www.abs.gov.au.*

ACIL Tasman Pty Ltd. 2005. Economics Policy Strategy. *Research into access to recycled water and impediments to recycled water investment.* Report prepared for the Australian Government Department of Agriculture, Fisheries and Forestry on behalf of the Natural Resource Policy and Programs Committee. June 2005, pp. 1-82.

Agodzo, S. K.; Huibers, F.; Chenini, F.; van Lier, J. B.; Duran, A. 2003. Use of Wastewater in irrigated agriculture. Country studies from Bolivia, Ghana and Tunisia, Vol. 2 (Ghana). WUR, Wageningen, the Netherlands.

Allison, L.; Tierney, J.; Lundy, K.; Mackay, S.; Tchen, T.; Wong, P. 2002. The value of water: inquiry into Australia's management o urban water. Report of the Senate Environment, Communications, Information Technology and Arts Reference Committee, Parliament of Australia, Canberra, ACT. *http://www.aph.gov.au/senate/committee/ecita_ctte/water/report*

Angyal, A. 1941. Disgust and related aversions. *Journal of Abnormal and Social Psychology* 36: 393-412.

ANZECC, ARMCANZ, NHMRC. 2000a. Guidelines for Sewerage Systems: reclaimed water. Paper No. 14. Australia and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand. Australia and New Zealand. National Water Quality Management Strategy. *http://www.deh.gov.au/water/quality/nwqms/*

ANZECC, ARMCANZ, NHMRC. 2000b. Guidelines for Sewerage Systems: effluent management. Paper No. 11. Australia and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand. Australia and New Zealand. National Water Quality Management Strategy. *http://www.deh.gov.au/water/quality/nwqms/*

ARCWIS (Australian Research Centre for Water in Society). 2002. *Perth domestic water use study Household appliance ownership and Community attitudinal analysis.* 1999-2000. Sydney: CSIRO Urban Water Programme.

ARRIS Pty Ltd. 2004. Quality Assurance Programs and Growing Crops with Recycled Water. Brochure funded by Horticulture Australia Ltd.

Bradford, A.; Brook, R.; Hunshal, C. S. 2003. Wastewater irrigation in Hubli–Dharwad, India: Implications for health and livelihoods. *Environment and Urbanization* 15(2): 157-170.

Bruvold, W. 1988. Public opinion on water reuse options. *Journal WPCF* 60(1): 45-49.

Buechler, S.; Mekala, G. D.; Raschid-Sally, L. 2002. Livelihoods and Wastewater Irrigated Agriculture along the Musi River in Hyderabad City, Andhra Pradesh, India. *Urban Agriculture Magazine* 8: 14-17.

Buechler, S.; Mekala, G. D. 2003. Wastewater as a Source of Multiple Livelihoods? A Study in Rural Andhra Pradesh, South India. In: Devi, R.; Ahsan, N. (Eds.), *Water and Wastewater: Perspectives of Developing Countries*. London, UK: International Water Association.

Buechler, S.; Mekala, G. D. 2005. *Household Food Security and Wastewater-dependent Livelihood Activities Along the Musi River in Andhra Pradesh, India.* Internet publication. *http://www.who.int/water_sanitation_health/wastewater/gwwufoodsecurity.pdf*

Buechler, S.; Mekala, G. D. Highlighting the User in Wastewater Research: Gender, Caste and Class in the Study of Wastewater-dependent Livelihoods in Hyderabad, India. In: Ahmed, S.; Gautam, S. R.; Zwarteveen, M. (eds.), *Engendering Integrated Water Management in South Asia: Policy, Practice and Institutions.* New Delhi: Sage Press. Forthcoming.

Bureau of Meteorology. 2006. Annual Report. 2006-07. Published by Bureau of Meteorology, Australian Government. *http://www.bom.gov.au/inside/eiab/reports/ar06-07/index.shtml*

Chalmers, P. E.; Williams, R.; Everest, P. E. 2002. 'Supercharged', *Civil Engineering*, January 2002.

Chattopadhyay, K. 2004. *Jalabhumir Kolkata – a fact-finding observation of East Calcutta Wetlands.* Kolkata (publisher unknown).

Cox, S. 2004. Alternative Water Sources: The Pimpana – Coomera Scheme, *Water* 31(3), May 2004.

CPCB (Central Pollution Control Board). 1995. Status of Water supply and wastewater generation, collection, treatment and disposal in metro cities (1994-95).

CPCB. 1998. Water Quality Status of Yamuna River.

Davey, A.; Miller, P.; Knops, F. 2005. Australia's Largest Ultra-Filtration Reclaimed Water Plant, *Water* 32(2), March 2005.

Department of Environment and Heritage. 1996. Portfolio Budget Statements 1996-97. *http://www.environment.gov.au/about/publications/budget/budget96/statement/index.html*

DIPNR (Department of Infrastructure, Planning and Natural Resources). 2004. *Meeting the challenges, Securing Sydney's water future.* The Metropolitan Water Plan.

Doyle, P. T.; Johnson, F. 2005. *Complexity of increasing water use efficiency on irrigated dairy farms.* Proceedings of Dairy Industry Association of Australia Conference.

Drechsel, P.; Blumenthal, U.; Keraita, B. 2002. Balancing Health and Livelihoods, Adjusting Wastewater Irrigation Guidelines for Resource-poor Countries. *UA Magazine No. 8.*

Ensink, J. H. J.; Mahmood, T.; van der Hoek, W.; Raschid-Sally, L.; Amerasinghe, F. 2004. A Nationwide Assessment of Wastewater Use in Pakistan: An Obscure Activity or a Vitally Important One? *Water Policy* 6: 1-10.

EPA (Environment Protection Agency). 2003. *Guidelines for Environment Management: Use of Reclaimed water.* Publication 464.2. ISBN 0 7306 7622 6. EPA, Victoria, June 2003. Available at http://epanote2.epa.vic.gov.au/EPA/publications.nsf/2f1c2625731746aa4a256ce90001cbb5/64c2a15969d75e184a2569a00025de63/$FILE/464.2.pdf

ESD. 1991..Final Report – Agriculture, Ecologically Sustainable Working Groups. AGPS, Canberra. ACT ESD 1991. Contact the Department of Environment and Heritage at *http://www.deh.gov.au*

Frewer, L. J.; Howard, C.; Shepard, R. 1998. Understanding public attitude to technology. *Journal of Risk Research* 221-235.

Government of India. 2006. Press releases from the Ministry of Statistics and Programme Implementation. *http://www.mospi.nic.in/mospi_press_releases.htm.*

Hamilton, A. J.; Boland, A.; Stevens, D.; Kelly, J.; Radcliffe, J.; Ziehrl, A.; Dillon, P.; Paulin, B. 2005. Position of Australian horticultural industry with respect to the use of reclaimed water. *Agricultural Water Management* 71: 181-209.

Hussain, I.; Raschid-Sally, L.; Hanjra, M. A.; Marikar, F.; van der Hoek, W. 2001. *A framework for analyzing socioeconomic, health and environmental impacts of wastewater use in agriculture in developing countries*. IWMI Working Paper 26.Colombo, Sri Lanka: International Water Management Institute.

Jellinek, S.; Milverton, D.; Martinez, G. A.; Schrader, K. 2006. World Bank Report: Water Utility Subsidies Benefit The 'Haves', Not The 'Have Nots'. News Release No:2006/317/ESSD. *http://web.worldbank.org*

Kaercher, J. D.; Po, M.; Nancarrow, B. E. 2003. *Water Recycling Community Discussion Meeting I* (unpublished manuscript). Perth: ARCWIS (Australian Research Centre for Water in Society).

Kularatne, D.; Ridley, D.; Cameron, C. 2005. Assumptions Associated with using Recycled Water for Primary Industries. Discussion Paper. Department of Primary Industries. Pp. 1-31.

Mantovani, P.; Asano, T.; Chang, A.; Okun, D. A. 2001. *Management practices for non-potable water reuse*. Project 97-IRM-6, Water Environment Research Foundation, Alexandria VA.

Mara, D.; Cairncross, S. 1989. Guidelines for the Safe Use of Wastewater and Excreta in Agriculture and Aquaculture. Geneva, Switzerland: World Health Organization.

Marsalek, J.; Schaefer, K.; Excall, K.; Brannen, L.;.Aidun, B. 2002. *Water Reuse and Recycling*. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba. CCME Linking Water Science to Policy Workshop Series. Report No. 3, 39pp.

Martyn, H.; Kaeding, V.; Heidenreich, C. 2005. Desalination Options for Salinity Management in the Northern Adelaide Plains, *Water* 32(3), May 2005.

McGuckian, R. 2002. Consequences of current and proposed water reform on Australian Horticulture. Preliminary draft report, commissioned by Horticulture Australia, October. Contact Horticulture Australia at *www.horticulture.com.au*

Mekala, G. D. 2006. Multi-stakeholder Processes for safe use of wastewater and sustainable urban, peri-urban agriculture – A case study of Hyderabad, India. Powerpoint presentation at the UN Habitat third World Urban Forum June 19-23, 2006, Vancouver, Canada.

Melbourne Water. 1998. Exploring community attitudes to water conservation and effluent reuse. A consultancy report prepared by Open Mind Group. St. Kilda, Victoria.

Muir, R. 2006. The economics of recycling. Power point presentation at the Water Recycling and Infrastructure Summit on 06 December 2006. Sydney. Synergies Economic Consulting.

Nadebaum, P. R.; Pamminger, F.; Moore, L. 2004. A Third Pipe Recycled Water Scheme: Business Risk Considerations, *Water* 31(3), May 2004.

Ogoshi, M.; Suzuki, Y.; Asano, T. 2001. *Water reuse in Japan. Water Science and Technology* 43(10): 17-23.

Pannell, D. J.; Marshall, G. R.; Barr, N.; Curtis, A.; Vanclay, F.; Wilkinson, R. 2005. *Understanding and promoting adoption of conservation practices by rural landholders.* Unpublished manuscript submitted to Aust. Jour. Exp. Agric. Accessed at *http://www.general.uwa.edu.au/u/dpannell/dp0502.htm*

Pescod, M. B. 1992. *Wastewater Treatment and Uses in Agriculture – FAO Paper 47*.

Po, M.; Kaercher, J.; Nancarrow, B. E. 2004. Australian Water Conservation and Reuse Research Program: Literature review of factors influencing public perceptions of water reuse. Australian Water Association. April 2004. pp 1-27.

Porter, C. 2005, Singapore Technotour, *Water* 32(3), May 2005.

Radcliffe, J. 2003. An overview of water recycling in Australia - results of a recent ATSE study. In: Proceedings of Water Recycling Australia: Second National Conference, Brisbane, 1-3 September 2003 (CD-ROM).

Radcliffe, J. 2004. *Water recycling in Australia.* Australian Academy of Technological Sciences and Engineering, Parkville, Melbourne.

Raghavendra, S. 2006. Re-examining the 'low water tariff' hypothesis: lessons from Hyderabad, India. *Urban Water Journal* 3(4): 235-247.

Raschid-Sally, L.; Doan Doan Tuan, Abayawardana, S. 2004. National Assessments on Wastewater Use in Agriculture an Emerging Typology: The Vietnam Case Study. In: Scott, C. A.; Faruqui, N. I.; Raschid-Sally, L. (eds.), *Wastewater use in irrigated agriculture: Confronting the livelihood and Environmental realities*. IWMI/IDRC-CRDI/CABI, Wallingford, UK.

Rozin, P.; Fallon, A. E. 1987. A Perspective on disgust. *Psychological Reports* 94: 23-41.

Sawhney, A. 2004. The New Face of Environmental Management in India. Ashgate Publishing, Ltd. ISBN 075461915X.

Scott, C.; Faruqui, N.; Raschid-Sally, L. 2004. Wastewater Use in Irrigated Agriculture: Management Challenges in Developing Countries. In: Scott, C. A.; Faruqui, N. I.; Raschid-Sally, L. (eds.). Wastewater Use in Irrigated Agriculture: Confronting the livelihood and Environmental realities. IWMI/IDRC-CRDI/CABI, Wallingford, UK.

Scott, C. A.; Zarazúa, J. A.; Levine, G. 2000. Urban-Wastewater Reuse for Crop Production in the Water-short Guanajuato River Basin, Mexico. IWMI Research Report 41. Colombo, Sri Lanka: International Water Management Institute.

Shukla, R. K.; Dwivedi, S. K.; Sharma, A. (with assistance from Sunil Jain). 2004. *The Great Indian Middle Class: Results from the NCAER Market information Survey of Households.* National Council of Applied Economic Research (in association with Business Standard).

South East QLD Recycled Water Task Force. 2003. South East QLD Recycled Water Task Force Report (unpublished). http://www.sd.qld.gov.au/dsdweb/docs-in/ppp/SEQ_Recycled_Water_Taskforce_Report.pdf

Strauss, M.; Blumenthal, U. 1990. Human Waste Use in Agriculture and Aquaculture: Utilization Practices and Health Perspectives. IRCWD Report 09/90. International Reference Center for Waste Disposal (IRCWD). Duebendorf, Germany.

Swiss Business Hub India & Heinz Habegger, Baleco AG, Thun. 2004. *Market Report: Opportunities for Environmental Technology in India. Focus on Water, Air and Hazardous Waste*. Swiss Business Hub India, 2004.

Swinton, B. 2005. Membrane technology. *Water* 36–41.

Sydney Water. 1999. *Community views on recycled water.* Sydney:

Solomon, Cheere. 2006. Irrigation Policies, Strategies and Institutional Support Conditions in Ethiopia. in: Awulacew, S.B.; Menkir, M.; Abesha, D.; Atnafe, T.; Wondimkun, Y. (Eds). 2006. *Best Practices and Technologies for Small Scale Agricultural Water Management in Ethiopia*. Procedings of a MoARD/MoWR/USAID/IWMI symposium and exhibition held at Ghion Hotel, Addis Ababa, Ethiopia 7-9 March, 2006 Colombo, Srilanka, International Water Management Institute.

Tadesse, K. 2004. Strategic planning for groundwater assessment in Ethiopia. A paper presented to International Conference and Exhibition on Groundwater in Ethiopia: from May, 25-27 2004. Addis Ababa: Ethiopia.

UNESCO (United Nations Educational, Scientific and Cultural Organization). 2004. National development report for Ethiopia, UNESCO, World Water Assessment Program, December 2004.

WAPCOS (Water & Power Consultancy Services (I) Ltd.). 1995. The National Water Resources Master Plan, Addis Ababa: Ethiopia.

Werfring, A. 2004. Typology of Irrigation in Ethiopia. A thesis submitted to the University of Natural Resources and Applied Life Sciences Vienna. Institute of Hydraulics and Rural Water Management in partial fulfillment of the degree of Diplomingeieur.

World Bank. 2005. World Bank Development Indicator (WDI).

Tisdell, J.; Ward, J.; Grudzinski, T. 2002. The development of water reform in Australia. Technical Report, 02/5, May 2002. Cooperative Research Centre for Catchment Hydrology (unpublished).

UNDP (United Nations Development Programme). 1998. Global Human Development Report 1998. Oxford University Press, New York.

Walker, T. 2003. Kwinana Water Reclamation Plant. *Water* 30(5), August 2003.

Water Corporation. 2005. Perths seawater desalination plant. Last accessed: 8 August 2005. http://www.watercorporation.com.au/docs/desal_faq.pdf

Winrock International India. 2007. Urban Wastewater: Livelihoods, Health and Environmental Impacts in India. Research report submitted to International Water Management Institute.

WSAA (Water Services Association of Australia). 2005. Testing Water-Urban water in our growing cities-the risks, challenges, innovation and planning. Position Paper No.01, October 2005. Published by Water Services Association of Australia (WSAA). Pp 1-30. http://www.wsaa.asn.au

YUVA, Mumbai. 2005. National Assessment of Wastewater Generation and Utilization: A Case of India. Unpublished.

Postal Address
P O Box 2075
Colombo
Sri Lanka

Location
127, Sunil Mawatha
Pelawatta
Battaramulla
Sri Lanka

Telephone
+94-11 2880000

Fax
+94-11 2786854

E-mail
iwmi@cgiar.org

Website
http://www.iwmi.org

International Water Management Institute

FUTURE HARVEST
IWMI is a Future Harvest Center supported by the CGIAR

ISBN: 978-92-9090-691-9