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Domestic water conservation

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The demand for water continues to grow. More people want more water each and every year. Should there be a limit to this growth? Will global warming and changing rainfall patterns force a halt to growth or at least slow down the rate of increase? Will economic realities force a reconsideration of water use? Should we expect every country to follow the pattern of ever-increasing demand and supply and ever-increasing standards of water quality found in the high-income countries? The resulting costs are significant.

Kalbermatten (1991) describes having a feeling of unease "that we may be condemning our colleagues in developing countries not only to repeat our mistakes - but by exporting our conventional wisdom, we may indeed prevent them from finding their own better solutions to their problems". He suggests that any re-examination of our approach to conventional water supply should start by considering water conservation.

This paper describes the situation in an atypical city, Arriyadh (Riyadh), in a high-income country, Saudi Arabia and considers the costs and benefits of a water conservation programme.

Water supply in Arriyadh

The total population of the city of Arriyadh in 1988 was 1,519,856, representing an increase of 9.4 per cent in just two years. It was estimated that the average number of persons per dwelling unit in the city was 6.34 (Alshaikh Abdulaziz, 1989) with an average of 7.7 for a Saudi household and 4.3 for a foreign household.

In 1989 when this study was carried out (Pickford and Franceys, 1989) approximately 950,000 m^3 of water was being supplied to the city each day, most of it coming from desalination plants on the Gulf, 450 km distant from the city. Although the water delivered to Arriyadh at such a high cost was equivalent to about 600 litres per person per day (lpd), the average domestic consumption was estimated by Al Salem (1988) to be 2,130 litres per connection from a study of approximately 60 connections in each of eight areas. This is equivalent to 247 lpd. Included within this figure is water used for the outside domestic 'green areas' averaging 165 litres/connection/day in winter and 267 litres/connection/day in summer (Khadam, 1989). The balance between water supplied and consumed represents 'unaccounted for water' which in different districts of Arriyadh is believed to range from 23 per cent to 74 per cent (Al Salem 1988).

In the past there had been no general awareness of any need for water conservation in Arriyadh as ample water was freely available. Islamic tradition expects availability of water, but also encourages economic usage. However the problem of rising groundwater in the city coinciding with the realisation of the cost of such a generous supply led to a consideration of the feasibility of water conservation. This study considers only domestic water conservation.

Domestic water supply and conservation

The first step in any domestic conservation programme is to introduce measures to reduce on-plot leakage including repair of reported or noticed leaks, sounding and monitoring of meters. Seventy per cent of repairs to leaks undertaken by the Riyadh Water Works are within premises (Al Salem, 1988).

In the Arriyadh distribution system night-time pressure is generally high, ranging from greater than 7 bar in High Zone to greater than 5 bar in Main Zone and in the Low Zone between 1 and 4 bar. High pressure results in increased leakage, the increase being greater that expected because cracks open under increased pressure. Pressure reductions can lead to a reduction in waste with capital costs repaid by resultant savings in two years. Sophisticated computer managed systems can monitor and adjust pressures in a system to reduce usage at night (largely waste) by up to 57 per cent leading to a reduction in overall daily demand of 5.3 per cent (Howarth and Olner, 1981). This was recommended for Arriyadh.

Most house connections in Arriyadh use 32 mm pipes, for which there is no justification, and from which wastage of water is inevitably higher than for smaller diameter pipes. These delivery pipes normally discharge to underground storage tanks with an average capacity of 27 cubic metres. Worldwide such tanks are unusual. The World Bank (1987) recommends that large tanks should become redundant or replaced by smaller ones or the volume should be reduced because of the likelihood of under-registration by meters during slow filling. In Arriyadh there is also the danger of leakage from tanks adding to the groundwater problem.

Meters are inaccurate at low flows, the inaccuracy being greater for the larger diameter meters found on the average 32mm pipes. Tests have shown that even for 15mm diameter meters the average under-registration of new meters in normal use exceeds 5 percent whereas with smaller diameter meters of 750 litres per hour rating, the average under-registration is about 2 percent World Bank (1987).

In general the accuracy of meters in Arriyadh has been found to be within specified limits. However, it should be noted that with estimates of 'unaccounted for water' averaging 50 per cent, one reason for this may be significant under-registration at low flows as tanks fill up slowly, notwithstanding the accuracy of the meters at normal flows.

Improving the accuracy of the metering does not lead directly to water saving but gives consumers a better understanding of their water use when traiffs are charged at a realisitic rate.

Water-saving devices

Domestic water conservations programmes are usually built around the promotion of water-saving devices. There are various devices, the most important being taps, showers and toilets.

Spray taps are used mainly for hand washing and have simple aerators to provide a 'thicker' flow pattern so that the perceived volume of water is greater than the actual amount used; they are reported (DAA, 1977) to reduce consumption from 19 to 9 litres per minute (lpm) and total domestic water use by 2 per cent. The new US standard aims to limit taps to a maximum flow of 7.5 lpm. BRE (1978) describes atomised sprays for hand washing, passing only 0.3 lpm at 3.5 bar. In tests, regular users took 26 seconds to wash their hands producing an average water use of 0.14 litres, being about 18 per cent of the amount used by conventional spray taps and only 6 per cent of pillar taps. Overall performance of this ultra low flow tap was rated as fair but was not generally recommended for home use.

Past US practice was to use showers that take between 30 and 38lpm according to the size and pressure of the spray fitting (although typically operated at two-thirds capacity) but the new standards limit flow to 9.5lpm. UK standards recommend a maximum flow of 11 lpm even though BRE (1978) reports that a satisfactory 'conventional' shower can be obtained with a flow rate of 2.4 lpm over an average length of 7.5 minutes. Showers take on average 25 per cent of the water used for baths.

Considerable amounts of water are used in flushing toilets, often in the region of 30 per cent to 40 per cent of total domestic use. Any reduction in this amount can produce significant savings. Traditional toilets in the US use 13-26 litres per flush and in the UK around 9-11 litres per flush. More efficient systems such as the dual flush, variable flush and low volume cisterns are forecast to produce reductions of 25 per cent, 40 per cent and 10 per cent in water use (BRE, 1978). The dual flush cistern discharges a full flush of 9 litres or a short flush of about 5 litres at the user's choice. Results of field trials comparing dual flush with conventional systems indicate a saving of about 26 per cent in the quantity of water used overall for flushing. In the trials Davidson and Webster (1983) had water meters and logging equipment installed in 26 houses and found that the 'normal' 9 litre WC used on average 11.9 litres/flush with the dual flush unit taking 5.3 litres and the user controlled variable flush WC using 5.4 litres.

The new standards in the US as enacted first in Massachusetts and more recently in California do not use the dual flush system but require the use of low-flow toilets at only 6 litres per flush (Vickers, 1990). Going a stage further, Foster et al (1988) introduced 4 litre flush toilets in Tuscon, USA, effectively reducing water requirements for flushing to less than 30 lpd as opposed to the normal 115 lpd. These systems have not been found to cause any blockages in sewer lines because of the reduced flushing water.

The advantage of all these water saving designs is that once fitted, the consumer has little involvement in consciously having to remember to conserve water.

Table 1 Potential water savings from residential interior fittings (Martin et al, 1986)

	Reduction	Potential savings
Showers	45 to 11 lpm	9-12%
Taps	19 to 6 lpm	0-2%
Toilets	19 to 13 lpf	10-18%
Pressure	5.6 to 3.4 bar	0-10%
Washing machine	100-200 to 60-70 litres/load	0-5%

Waste water collection disposal and reuse

Raw or treated sullage (greywater) is suitable for toilet flushing and lawn-watering. Milliken and Taylor (1981) suggest that "recycling systems have proven to be both manageable and reliable, with no impairment of toilet operation and significant effects on lawn growth or appearance" giving typical savings of around 50 lpd.

To simplify performance requirements, many reuse systems process only the wastewater from bathing, laundry and sink usage. Siegrist et al (1981) investigate the raw greywater quality and found that "when compared to total residential wastewater, greywater possesses lower concentrations of most conventional pollutants with the exception of BOD 5. If the kitchen sink wastes are excluded, the pollutant concentrations in the greywater are significantly lower than in the total residential waste stream."

In Arriyadh with an average of 10% of household water consumption used on the outside 'green areas' waste water reuse systems could work eficiently on an household basis, emulating the reuse of waste water on public green areas in the city.

Legislative and administrative conservation measures

The management of the Riyadh Water Works is fully committed to water conservation and had instituted a vigorous programme that included leakage detection and control, meter maintenance and billing.

Revision of building and plumbing codes to require installation of water saving fixtures can be an effective water conservation measure. In Arriyadh materials have to conform to international standards for major contracts, but domestic plumbing and fitments are inadequately covered by regulations. There are no requirements to install water saving devices.

Recognised training and qualifications for staff are vital to maintain the required level of skills. In Arriyadh no qualifications are required and the standard of workmanship is generally poor. Supervision of work in domestic buildings is reported to be either non-existent or inadequate.

Both a revision of the bye-laws and a requirement for staff training should be instituted in Arriyadh.

Tariffs and fiscal conservation measures

Experience in many countries shows that appropriate use of tariffs is an effective water conservation measure. Milliken and Taylor (1981) quote: "for a water supply agency seeking to motivate more efficient use of water nothing is as simple, comprehensive and effective as the pricing mechanism"

For example, average consumption in Perth, Australia, fell from 500m^3 to 300m^3 after metering and tariffs were introduced and 50 per cent of households rearranged their gardens to reduce water use. (Thomas & Syme, 1988)

In a similarly arid climate in southern Arizona, Billings and Day (1989) estimated long-term price elasticities of -0.72 with a temperature elasticity of +0.63 and an income elasticity of +0.31. In Kuwait, Al-Qunaibet and Johnston (1985) found price elasticities of - 0.77.

The charge in Arriyadh for average water use was SR 15 per month (SR 6.40 to £1), representing a purely nominal amount giving ample scope for increasing prices to encourage conservation. By the time of the sudy a comprehensive meter checking programme and renewal of billings even at this low rate had already resulted in a 12 per cent reduction in demand.

Awareness enhancement for conservation

For any water conservation programme to succeed the public need to be convinced of its importance. They also need information and suggestions on how to implement conservation measures. Some research in USA indicates that technological measures such as minimum flow fittings require significant public awareness campaigns to achieve major water saving.

In carrying out the survey, Sims et al (1982) asked householders 'if the price of water was increased by 25 per cent what conservation measures would be adopted?' It is significant that 56.9 per cent said they would not change their behaviour in any way. When a 100 per cent increase in water tariffs was proposed, 27 per cent of respondents still said they would take no action. This survey does not agree with the price elasticities quoted above but it is against this possible background that public awareness and domestic water conservation programmes must be carried out.

This study is relevant to Arriyadh because it indicates that major water savings will come from the use of minimum flow fixtures and fittings but that these technological measures will only enhance water conservation where a significant public awareness campaign is also undertaken as well as tariff changes.

Costs and benefits

The benefits to be gained from a domestic water conservation programme in Arriyadh could be quantified according to the value of water production saved, the value of deferred construction in new water works, the value of property damage prevention from rising groundwater, the value of improved revenue collection from improved meter reading and higher tariffs, the value of saving in leak repair crew time, the value of improved public relations, the value of social benefits arising from reduced nuisance, the value of reduced sewage treatment costs and the value of deferred construction of sewage treatment facilities.

There is a wide variety in the estimates of the cost of providing this water in Arriyadh. Allowing for the high unaccounted for water, the cost of water supplied to householders is estimated to be between SR 10.4 and SR 29.2 per cubic metre. SR 20 m^3 represents a reasonable mean cost of water delivered to households. For sewered areas the cost of sewerage and sewage treatment is equivalent to an additional SR 6.6 m^3. The average cost of emptying pits for householders without sewerage is equivalent to SR 4.9 per cubic metre.

This study takes two figures as representative of the benefits. The first is the generally accepted cost of producing water, that is the marginal cost of SR 8/m^3. With the imminent completion of a third water supply pipeline from El Jubail to Qasim via Arriyadh there is unlikely to be any significant new construction for water supply. The concept of benefits of deferred construction is not therefore relevant in this case. Added to the marginal cost of water must be the cost of disposing of the waste water. A figure of SR 5/m^3 has been taken as representing an average of the costs of sewerage and tanker disposal of waste water.

Costs of introducing water conservation measures in Table 2 have been calculated assuming that systems are being converted from existing - costs for new households would be significantly reduced. Using the information given above on potential savings it is possible to deminstrate that more water can be saved than is presently used. To avoid this problem an average household is considered with estimates of potential saving in each of the areas of normal use.

Conclusion

In California during a period of drought it was found that 'rigorous programmes' ('rigorous' according to the stringency of regulations and penalties) achieved a 55 to 60 per cent per capita reduction in domestic water use, 'moderate programmes' delivered from 41 to 47 per cent and 'mild programmes' from 6 to 19 per cent reduction (Dawdy & Young in Yejevich, 1983). Hanke and Mehrez (1979) found that in Perth, Australia, the elasticities in demand are in the range from -0.162 to -0.222 with 'light restrictions', leading to a monthly reduction of 14.3 per cent to 10.6 per cent.

In the context of Arriyadh, people do not perceive any shortage of water and from the conservation viewpoint it is unlikely that anything greater than a 'mild programme' would be socially acceptable. Therefore the most that could reasonably be achieved in changing the way people use water in the short term would be in the range of up to 15 per cent, using a combination of all the conservation approaches outlined above.

The city of Arriyadh is in many ways a special case. However the potential savings demonstrated in this study could be obtained in many other cities. Although the ratio of costs and benefits may vary according to the lower water costs generally found elsewhere, the reduced affordability in low-income countries may lead to a greater appreciation of these benefits.

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Table 2 Costs and benefits - average per person over a ten year lifecycle

	Present Average Use	Potential Benefits Savings (10yrlifecycle)		Costs	Method
Pressure reduction	12.5lpd		SR 590	SR 24	
Drinking/cooking	10 lpd				
Dishwashing	10 lpd	1.3lpd	SR 62	SR 2	Leaking taps
		5 lpd	SR 238	SR 8	Aerator taps
Laundry	30 lpd	10 lpd	SR 476	SR 275	Low water machines
Bathing	105lpd	80 lpd	SR 3,800	SR 10	Low flow showers
Toilet Flushing	90 lpd	60 lpd	SR 2,850	SR 100	Dual flush toilets
Irrigation/cleaning	25 lpd	3 lpd	SR 88	SR 3.5	Evapotranspiration Prog.
	(or	11 lpd	SR 328	SR 240	Automatic sprinklers)
TOTALS	270lpd	172lpd	SR 8,104	SR 423	
Additional benefits from reuse assuming all other conservation measures being employed)					
Greywater Reuse		52 lpd	SR 2,470	SR 1,420	

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