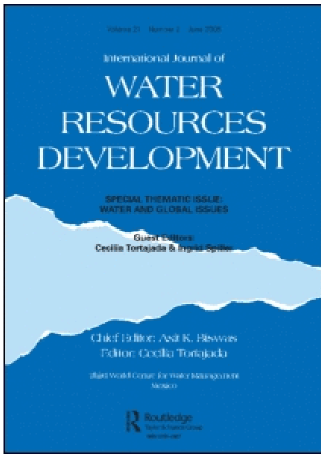

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Urban Water Management in Developing Arid Countries

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ABSTRACT *Urbanization, industrialization and rapid population growth in developing countries of the Arabian Peninsula are putting increasing pressure on local water authorities and water planners to satisfy the growing urban water and sanitation demands. In the Arabian Peninsula, water resources are limited, average rainfall is low and the seawater and brackish water desalination in addition to limited groundwater resources are the major water supply sources. The population increased from about 17.688 million in 1970 to 38.52 million in 1995 and is expected to reach 81.25 million in 2025. The urban population is expected to rise from 60% in 1995 to more than 80% in 2025. The domestic water demand is expected to rise from 2863 million cubic metres (MCM) in 1990 to about 4264 MCM in 2000 and 10580 MCM in 2025. In Saudi Arabia, the population increased by 143.6% between 1970 and 1995; and it is expected to reach about 40.426 million in 2025, with about 80% urban population. The domestic water demand in the Kingdom is expected to be about 2350 MCM in 2000 and 6450 MCM in 2025. Specialized agencies have been established for water production and distribution, and for wastewater collection, treatment and reuse. Special legislation has been introduced to manage water demands and to protect the interests of the community and its natural resources. Fifty-seven costly desalination plants have been constructed in the Peninsula on the Gulf and Red Sea coasts, as well as water transmission lines to transport the desalinated water to coastal and inland major cities. The seawater desalination unit cost is about US\$0.70/m^3 for a large desalination plant with energy priced at world prices. More than \$30 billion has been invested on water and sanitation projects. Present desalination production is about 46% of the total domestic demand, and the rest is pumped from deep and shallow aquifers. In general, fragmented legislation and institutional arrangements and low water charges have indirectly resulted in over-usage of domestic water, production of excessive quantities of wastewater, significant leakage, and enhancement of shallow water-table formation and rise in some cities. Facing the challenges of satisfying the growing urban water demands requires several essential measures such as: (a) introduction of new technologies to reduce water demands, and losses, and to enhance wastewater recycling and water conservation; (b) the updating of legislation to coordinate both responsibilities and actions among different water agencies; (c) the introduction of a strong and transparent regulatory framework to adopt different forms of water supply privatization, to reduce the costs of building, operation and maintenance of water and sanitation facilities, and to improve the level of services and billing, leakage and wastewater collection and treatment; (d) an increase in water tariffs to reflect the actual value of the water, and to enhance the awareness of*

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public as to the value of water; and (e) development of short-term and long-term national water plans based on realistic water demand forecasting.

Introduction

There are estimates that urban population in developing countries may double in 15 years. Rapid urbanization, industrialization and population growth in these countries are exerting increasing pressure on local water authorities and water planners to satisfy the growing urban water and sanitation demands. This is even more challenging in developing arid countries such as those of the Arabian Peninsula, which includes Saudi Arabia, Kuwait, United Arab Emirates (UAE), Bahrain, Qatar, Oman and Yemen (Figure 1). In the Peninsula, the annual precipitation is less than 150 mm/year and the available water resources are limited. Because of the lack of availability of conventional sources of fresh water for drinking purposes, seawater and brackish water desalination, in addition to limited groundwater resources, are the major water supply sources for urban uses. Urban water demands have increased substantially, especially during the last two decades, due to rapid urbanization and industrialization, population growth and improvement in living standards. With a high average growth rate of more than 3.4% the population increased from about 17.688 million in 1970 to 38.52 million in 1995 and is expected to reach 81.25 million in 2025. The urban population is expected to rise from 60% in 1995 to more than 80% in 2025 (Figure 2). The region is expected to become predominantly urban in the next 25 years. The Arabian Peninsula countries have invested heavily to build seawater and brackish water desalination plants and wastewater collection and treatment facilities. Satisfying the growing water and sanitation demands require the construction of additional costly water and sanitation projects. This represents major technical, management and financial challenges to policy makers. This paper describes the development of urban water and sanitation demands and supplies, and the urban water management practices in the countries of the Arabian Peninsula in general, and in Saudi Arabia in particular. It also defines the present challenges and the measures required to achieve effective urban water and sanitation management.

Urban Water Demands

The urban water consumption includes industrial and domestic uses. The domestic uses include residential, commercial, public buildings, facilities, and water losses from the distribution networks. The residential water consumption represents more than half of the domestic water use.

Domestic Water Demand

During the last two decades, urban water demand has increased rapidly in the countries of the Arabian Peninsula as a result of high population growth, improvement of living standards, rapid urbanization and industrialization. The urban population in the Peninsula has increased from 6.08 million in 1970 to about 23.12 million in 1995, and is expected to rise to 33.38 million in 2000 and to 65 million in 2025 (see Figure 2). The domestic water demand in the Arabian Peninsula is expected to rise from 2269 MCM in 1990 to about 4264 MCM in 2000

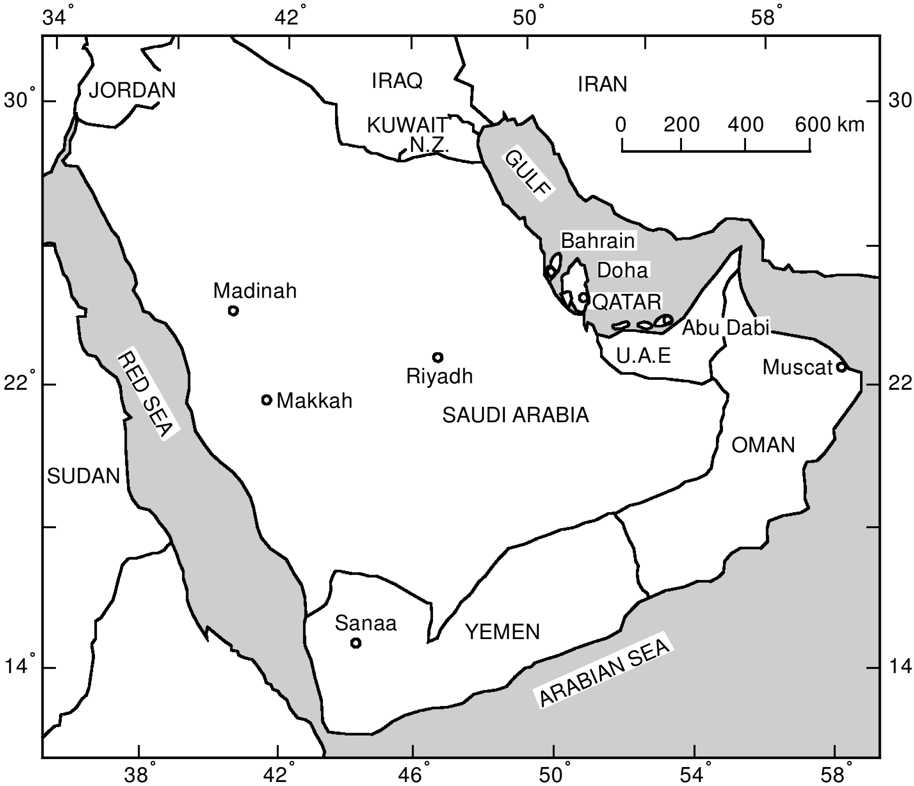

Figure 1. Location of Arabian Peninsula countries.

and to about 10 580 MCM in 2025 (Figure 3). The domestic water consumption represented 10% of the total water use in 1990, and it is expected to rise to about 16.26% and 28.52% in 2000 and 2025 respectively. This indicates clearly the impact of urbanization on the domestic water demand in countries of the Arabian Peninsula.

In Saudi Arabia, the population of the Kingdom increased by 143.6% between 1970 and 1995, and it is expected to increase by another 114% between 1995 and 2025 when it will reach 40.426 million (see Figure 2). The urban population increased from 3.74 million in 1970 to 15.84 million in 1995. It is expected to reach 32.3 million in 2025, about 80% of the total population of the country. Consequently, it can be observed that the domestic water ratio has increased from about 7.0% of the total national water use in 1990 to 9.2% in 1995, and it is expected to rise to 13.2% and 26.6% in 2000 and 2025, respectively (see Figure 3), reaching a very high 6450 MCM in 2025.

Riyadh City is a good example of the urbanization of cities in the Kingdom. The City has experienced phenomenal growth in terms of urbanization and population: from less than one km^2 in 1918 to about 1600 km^2 in 1997 (Taher & Al Saati, 1999). About 80% of that increase occurred during the last two decades. The population of Riyadh has increased, from 1.094 million in 1980 to 2.98 million in 1995, and is expected to reach about 3.608 million and 6.795 million in 2000 and 2025 respectively (Al Hajji & Abu Aba, 1999) (Table 1). The daily water consumption has increased from 0.219 million m^3/day in 1980 to 1153

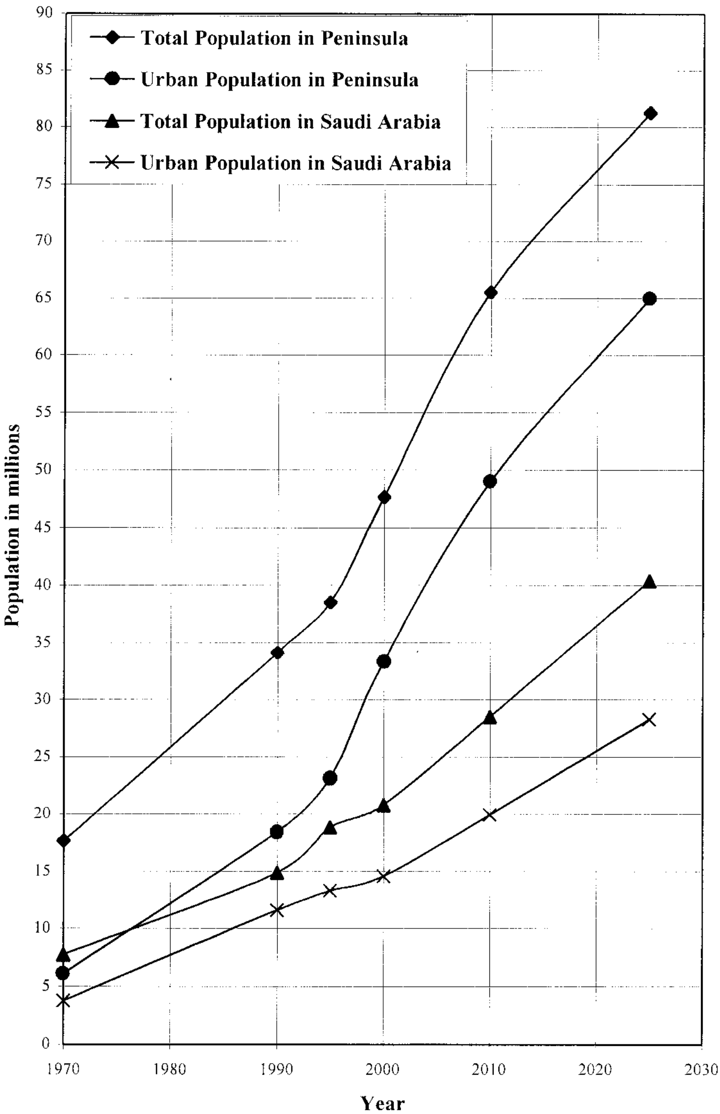

Figure 2. Past, present and projected population of Arabian Peninsula countries and Saudi Arabia.

million m^3/day in 1995; it is expected to reach 1.551 million m^3/day and 3.098 m^3/day in 2000 and 2025 (Table 1). The number of house connections to the water network has increased, from 83 222 in 1980 to 219 037 in 1995; it is expected to reach 263 975 and 499 670 in 2000 and 2025 (Table 1).

Industrial Water Demand

The industrial water demand in the countries of the Peninsula has grown rapidly during the last two decades as a result of significant industrial development. The industrial structure in these countries consists mostly of petrochemicals, cement, steel, fertilizers, mining, basic metals, textiles, and food and

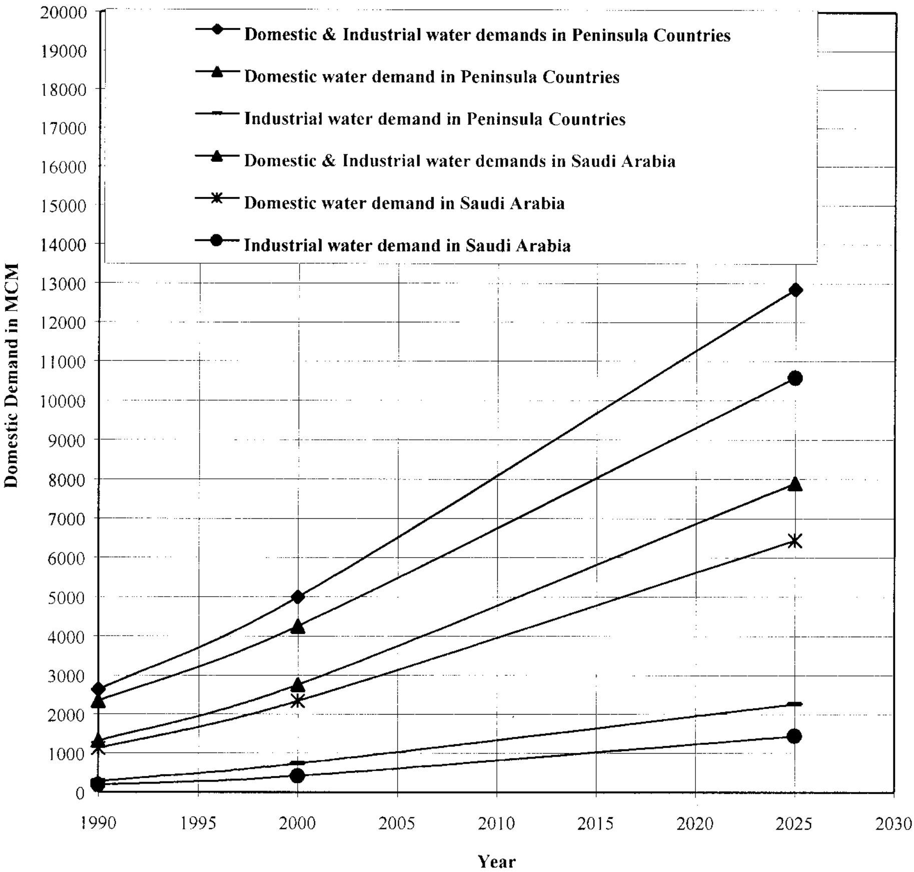

Figure 3. Past, present and projected water demands of Arabian Peninsula countries and Saudi Arabia. *Source*: Compiled by the ESCWA secretariat from country papers, regional and international sources, 1992, 1994, 1996 and 1997.

Table 1. Past, present and projected urban population growth, water consumption and number of house connections in Riyadh city (1980–2025)

Year	Population	Water consumption (M^3/day)	Water consumption (l/c/d)*	No. of connections
1980	1 094 516	219 912	2009	83 222
1985	1 723 092	584 445	339	137 647
1990	2 351 669	851 304	362	187 576
1995	2 980 245	1 153 569	387	219 037
2000	3 608 822	1 551 195	429.83	263 974
2005	4 237 394	1 872 555	441.9	307 975
2010	4 865 198	2 181 220	448	330 125
2020	6 152 899	2 787 263	453	452 419
2025	6 795 514	3 098 754	456	499 670

Notes: *Litres per capita per day. *Source*: Al-Hajji & Abu Aba (1999).

beverage production. Although the industrial water demand represents a small percentage of the demand at the national level, some industries requires special qualities. At the regional level, the industrial demand is expected to increase from about 1.2% in 1990, to 3.38% in 2000 and to 6.12% in 2025 respectively (see Figure 3).

In Saudi Arabia, the industrial demand is expected to rise from 190 MCM or 1.16% of the total national water use in 1990 to 415 MCM or 2.33% in the year 2000, and 1450 MCM or 6% in the 2010 (see Figure 3). The growing industrial water demand is mainly satisfied from desalination plants and from non-renewable groundwater resources. The industrial sector produces large quantities of wastewater at plant level.

Water and Sanitation Supplies

Water Supplies

About 75% to 97% of the urban population in the Peninsula countries have access to drinking water. The large growth in urbanization and water demand has required large investments for construction of desalination plants, storage facilities, water transportation and distribution networks. Large seawater desalination plants have been constructed on the Gulf and Red Sea coasts to produce suitable drinking water. Water transportation pipelines have been constructed to transport desalinated seawater from the coasts to coastal and inland cities and towns such as Riyadh, Makka, Medina and Taif. In 1992, about 80% of the desalination capacity in the Arabian Peninsula used multi-stage flash systems (MSF), while the remaining plants used reverse osmosis (RO) (Alawi & Abdulrazzak, 1993). Total desalination production is expected to reach about 60% of the world production in 2000 (Authman, 1999). The total number of desalination plants in 1995 was 57: 35 MSF and RO plants in Saudi Arabia, eight in UAE, six in Kuwait, three in Bahrain, two in Qatar, one in Yemen and two in Oman. In 1997, Saudi Arabia became the largest desalinated water producer in the world. The desalination plants' capacities ranged from 1000 m^3/day to 789 864 m^3/day in 1997 (Bushnak, 1997) (Table 2).

Figure 4 shows the water resources of the countries in the Arabian Peninsula in 1996 (ESCWA, 1997). Total desalination production was about 1683.9 MCM in 1996. This represents about 47% of the total domestic and industrial water demand in 1996, which was about 3567.7 MCM. The rest of the water is from limited surface water and mostly from groundwater resources in shallow and deep aquifers. The desalinated water supplies vary among these countries. In 1990, desalination water production was about 43%, 79% 63% and 5% of total domestic and industrial demands in Saudi Arabia, Kuwait, UAE and Yemen respectively (Table 3). To meet the increasing domestic and industrial demand, the total desalination capacity is expected to increase from 982 MCM in 1990 to about 2669 MCM in 2000. By the year 2000, the desalination production is expected to be about 38%, 89%, 99% and 23% of the total domestic and industrial demands in Saudi Arabia, Kuwait, UAE and Yemen respectively.

In Saudi Arabia, about 97% of the houses in the country are supplied with clean drinking water. The total desalination production in 1997 was about 719 MCM and expected to increase to 1057 MCM by the year 2000 to meet the growing domestic demand (Al-Ghamdi, 1997). The seawater desalination unit

Table 2. Major seawater desalination plants and their capacities in Saudi Arabia (1997)

Plant	Capacity (m^3/day)	Process
West Coast:		
Jeddah II	37 850	MSF
Jeddah III	65 700	MSF
Jeddah IV	189 250	MSF
Jeddah RO1	48 827	RO
Jeddah RO2	48 827	RO
Shouibah I	181 860	MSF
Shouibah II	378 787	MSF
Yanbu I	181 860	MSF
Yanbu II	99 000	MSF
Yanbu RO	128 000	RO
Asir I	75 700	MSF
King Faisal Naval Base I	7 500	MSF
King Faisal Naval Base II	7 500	RO
Haql II	3 785	RO
Duba III	3 785	RO
Umlujj II	3 785	RO
Azizia I	3 870	MED
Dahban JTC	3 500	RO
Jeddah ADC	3 400	RO
Al-Birk I	1 952	RO
KAAA I	4 000	MSF
KAAA II	2 000	RO
KFIP	2 000	RO
Saudia City	4 000	MSF
Saudia City	2 000	VC
Farasan	1 000	MSF
East Coast:		
Jubail I	116 035	MSF
Jubail II	798 864	MSF
Jubail RO	90 909	RO
Al-Khober II	193 536	MSF
Al-Khober III	227 272	MSF
Al-Khafji II	18 624	MSF
Tanajib	13 600	RO
Al-Safaniya	3 785	RO
Ras Mesa'ab	1 450	RO

Source: Bushnak, 1997.

cost is about US$0.70 per cubic metre for a large MSF desalination plant with energy priced at world prices (Bushnak, 1997). The plant also generates electricity, which is supplied to the regional power company. A more realistic seawater desalination cost for a medium-capacity plant which also produces electricity is about US$0.90 per cubic metre. The water supply costs vary among the countries of the Peninsula and even among different sectors of the country. The water supply cost is about US$1/cubic metre in Saudi Arabia, and about US$1.63 per cubic metre in Kuwait for desalination water (ESCWA, 1997). The transportation costs of one cubic metre from Jubail desalination plant to Riyadh at a distance of 460 km and at an elevation of about 620 metres above sea level is about US$0.2/$m^3$.

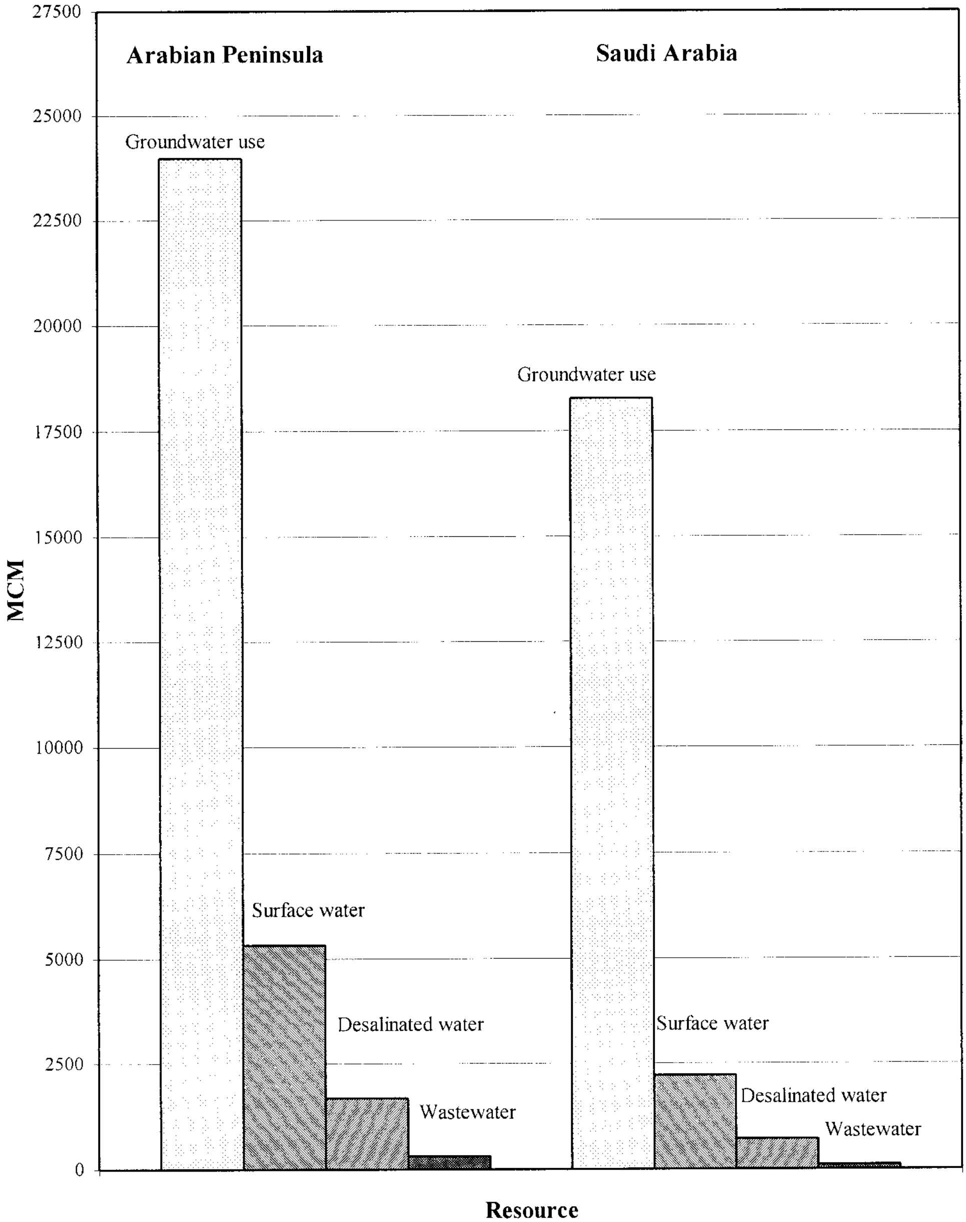

Figure 4. Water resources of the Arabian Peninsula countries and Saudi Arabia in 1996. *Source*: ESCWA (1997), Alawi & Abdulrazak (1993), Dabbagh & Abderrahman (1997), and personal estimation.

Sanitation Supplies

The extent of wastewater facilities varies among countries and regions in the Peninsula. Generally, the available treatment facilities in the region are sufficient to treat about 40% of the generated domestic wastewater (Alawi & Abdulrazzak, 1993). This shows that there is still a large gap between produced and treated wastewater. The secondary and tertiary treatment levels are used mostly in the region. The regional reused treated wastewater in the Peninsula was about 315

Table 3. Domestic and industrial demand and desalination production in countries of Arabian Peninsula in 1990 and 2000

	1990			2000		
		Desalination production			Desalination production	
Country	(D + I)* MCM	MCM	% of (D + I)	(D + I)* MCM	MCM	% of (D + I)
Bahrain	103	56	54	195	115	59
Kuwait	303	240	79	480	428	89
Oman	87	32	37	255	68	30
Qatar	85	23	27	105	2.6	3
Saudi Arabia	1340	580	43	2765	1057	38
UAE	540	342	63	780	772	99
Yemen	199	9	5	420	10	23
Total	2657	982	36.95	5000	2669	53.38

Note: *(D + I) Domestic and industrial demand in MCM. *Source:* Modified after ESCWA, 1997

MCM in 1996. This represent about 11% of the total used domestic water in the Peninsula (ESCWA, 1997).

In Saudi Arabia about 55% of the houses in some cities are connected to the municipal sewage network, and the remainder depend on septic tanks. It is estimated that about 1000 MCM of wastewater were generated in the country in 1996, and this is expected to increased to about 1500 MCM by the year 2000. The volumes of collected and treated wastewater were about 526 million in 1996, which represented about 42% of the total municipal water (Al-Rehaili, 1997). In 1996, the reused treated wastewater was about 127 MCM. It was reused mainly for irrigating agricultural crops and landscape plants and in refineries. This represents about 24% of the treated effluents and about 7% of the generated wastewater in 1996. Treated wastewater reuse in the Kingdom is expected to reach about 473 MCM in the year 2000 and 1000 MCM in 2010. The industrial sector produces large quantities of wastewater at plant level. To minimize industrial water demand, and maximize wastewater recycling and to protect the environment, large industrial cities have been established in different parts of the Kingdom. There are tens or hundreds of factories per city. The industrial wastewater is collected, treated and recycled within each city at plant level for industrial and landscape purposes. The industrial cities have specifications for the quality of the wastewater collected from factories. Generally, significant quantities of the effluents are still not utilized. A new approach called the closed water cycle has been introduced to industrial plants to maximize wastewater recycling, minimize wastewater disposal, reduce groundwater pumping and to protect the environment.

Institutional and Legal Considerations

In countries of the Peninsula, water-related institutional arrangements and legal measures are in accordance with Muslim laws 'Shari'a'. Water is considered as one of the natural resources and is the main component of the sustainability of the nation's life and security. The governments of the region have introduced specialized water agencies, regulations and measures to produce, treat and distribute the required qualities and quantities of water for all purposes, and to achieve effective water demand management. During the last decade, significant efforts were made to strengthen institutional arrangements, and to review and modernize water laws. In Saudi Arabia, Kuwait, Qatar, UAE, Bahrain, Oman and Yemen there are ministries and authorities responsible for water supply and wastewater collection and treatment.

For example, in Saudi Arabia, specialized agencies have been established for water production and distribution. Special regulations were introduced to manage water demand and to protect the interests of the community and its natural resources. The Ministry of Agriculture and Water (MAW) was established in 1953, and was assigned the responsibility to produce water and satisfy the demand in terms of quantity and quality. The Saline Water Conversion Corporation (SWCC) was established as a Ministerial agency under the MAW in 1965, then as an independent corporation within the MAW in 1974, to be responsible for the construction, operation and maintenance of desalination plants for drinking water production. The Water and Wastewater Authority (WWA) is an independent agency under the Ministry of Rural and Municipal Affairs, to distribute drinking water, and to collect and treat wastewater in different cities and towns of the country. Water management-related laws and regulations have been issued, including measures to reduce water demand and to augment the available water resources. In 1993, Law No. 7 was issued in UAE to establish the Federal Environmental Agency with a mandate to protect the water resources and introduce water standards. In Bahrain, decree No. 12 in 1980 and its addendum in 1982 were issued to regulate groundwater pumping, to protect its quality and to meter the water consumption at farm level. In Qatar, decree No. 13 was issued in 1994 to improve water resources protection by transferring the Environmental Protection Committee to the Ministry of Municipal Affairs

Water Pricing

Water and sanitation projects in the Arabian Peninsula are heavily subsidized by the governments concerned. The houses connected to municipal networks are charged according to a special water tariff designed by each country, or on a monthly basis. Water tariffs differ among countries and users. The tariff system is structured on increasing block rates or volume rates (Alawi & Abdulrazzak, 1993) (Table 4). In general, water charges are much lower than the actual costs of water production and distribution. In most countries of the Peninsula, the consumer pays less than one quarter of the actual production costs. In developed countries such as Germany, Belgium, France, The Netherlands, UK and Canada, the consumer pays \$1.71, \$1.31, \$1.27, \$1.27, \$1.1 \$0.41 per cubic metre of domestic water. This represents, approximately, the actual water costs in these countries. Comparison of these prices and those of the water tariff in the Arabian Peninsula shows clearly that with the exception of Oman and Yemen, the medium-sized family pays less than 20% of the water price in developed countries. It is necessary to reconsider this issue in order to conserve water resources and reduce the resultant wastewater volumes.

Large investments are needed to expand the existing wastewater collection and treatment facilities, and to construct new facilities. In Saudi Arabia, the costs of wastewater treatment range from about \$0.16/m^3 to \$0.75/m^3 depending on the treatment level and plant capacity (Ukayli & Husain, 1988). In Oman it

Table 4. Water tariffs in Arabian Peninsula countries

	Monthly tariff*	Type/use	$/m^3
Saudi Arabia	0.15 SR/M3 1–100 M^3	Potable	0.04
	1.00 SR/M3 101–200 M^3	Potable	0.27
	2.00 SR/M3 201–300 m^3	Potable	0.53
	4.00 SR/M3 > 300 M^3	Potable	1.07
Kuwait	0.800 KD/1000 gal	Potable domestic	0.58
	0.250 KD/1000 gal	Potable industrial	0.18
	0.100 KD/1000 gal	Brackish domestic	0.07
	0.100 KD/1000 gal	Brackish industrial	0.07
	0.200 KD/1000 gal	Brackish agricultural	0.15
Bahrain	0.025 BD/M3 < 60 M^3	Potable domestic	0.07
	0.080 BD/M3 < 61–100 M^3	Potable domestic	0.21
	0.200 BD/M3 > 100 M^3	Potable domestic	0.53
	0.300 BD/M3 < 450 M^3	Potable industrial	0.80
	0.400 BD/M3 > 450 M^3	Potable industrial	1.06
	0.002 BD/M3 < 60 Mm^3	Brackish	0.01
	0.025 BD/M3 < 61–100 M^3	Brackish	0.07
	0.085 BD/M3 > 100 M^3	Brackish	0.23
Qatar	4.40 QR/M^3 free for citizens	Potable	1.21
UAE	15.00 DH/1000 gal	Potable	0.90
Oman	2.000 OR/1000 gal	Potable	1.14
	3.000 OR/1000 gal	Potable	1.71
Yemen	5.40 YR/M3 < 10 M^3	Potable	0.50
	6.90 YR/M3 < 11–20 M^3	Potable	0.64
	9.50 YR/M3 21–30 M^3	Potable	0.88
	12.60 YR/M3 31–40 M^3	Potable	1.16
	15.50 YR/M3 < 40 M^3	Potable	1.43

* SR, KD, BD, QR, DH, OR and YR are local currencies.
Source: Alawi & Abdulrazak (1993).

ranges from $1.53 to $1.74/m^3; and in UAE, the cost of wastewater collection and treatment was about $0.3/ m^3, and about $0.4/ for reuse (ESCWA, 1997).

Water Demand Management

All countries of the Peninsula have recognized the magnitude of the increase in urban water demand and sanitation requirements, especially during recent decades. National programmes have been developed in UAE, Kuwait, Oman, Saudi Arabia, Bahrain, Qatar and Yemen to enhance leakage control in domestic water networks, and wastewater treatment and reuse for industrial and irrigation purposes. The quantities of wastewater reuse are expected to increase from 315 MCM in 1996 to about 1161 MCM in 2000 and to about 1570 MCM in 2010 (ESCWA, 1997; Alawi & Abdulrazzak, 1993). In UAE, wastewater reuse is expected to increase from 108 MCM in 1996 to 200 MCM in 2000 and to 250 MCM in 2010. In Oman, wastewater reuse is expected to increase from 5.5 MCM in 1996 to 50 MCM in 2000 and to 61 MCM in 2010. In Yemen, the use volumes are expected to increase from 6 MCM in 1996 to 36 MCM in 2000 and to 57 MCM in 2010. Leakage control measures have been introduced to these countries to minimize water losses from distribution and house networks.

In Saudi Arabia, water management-related laws and regulations have been developed, including those to reduce water demands and losses and to augment the available water resources. Examples are the introduction of leakage detection and control measures in domestic water supply networks, the adoption of water tariffs to enhance water conservation, recycling of ablution wastewater for toilet flushing, recycling of the ablution and bathing wastewater in multistorey and high-rise residential buildings for toilet flushing, and transportation and use of highly saline water in place of desalination water for toilet flushing in the Holy Mosque at Makka. A special Fatwa (Islamic Permission from the Council of Islamic Leading Scholars) has been issued to permit the reuse of wastewater effluents especially for irrigation (this Fatwa has helped in the reuse of millions of cubic metres of treated domestic effluents every year for irrigation).

Environmental Impacts

Some studies have suggested that limited negative impacts on the environment have resulted in some parts of the Peninsula from water projects. The source of energy to desalination plants, such as fuel used to generate the steam or electric power for the process, causes air pollution. Eliminating such pollution is costly but necessary. The discharge of brine water in the seawater of the Gulf has limited impacts on the small area close to the hot brine outfall. The process of dilution is effective in reducing the temperature of the hot brine and balancing its salt concentration (Bushnak, 1997). The aquatic organisms are sometimes removed from seawater when it is screened and filtered in plants, and some of the organisms are damaged if they are small enough to pass through the screen and filters of the plants. The uncontrolled inland disposal of brine water from RO plants causes serious pollution to shallow and deep aquifers. It also contributes significantly to shallow water-table formation and rise in and around cities. This problem has been experienced in a few cities along the coasts of the Red Sea and Gulf and inland. Elimination of these problems through proper disposal and treatment measures is extremely important to protect the groundwater resources and the environment.

Uncontrolled leakage from water supply networks in some cities contributes significantly to shallow water-table formation, rise, and contamination of shallow and deep aquifers. The excessive pumping from local aquifers to satisfy the increasing urban water demand results in considerable decline in water levels and deterioration in groundwater quality in some specific places.

Further Actions to Improve Urban Water Management

With a continuous rise in urban demand for water and sanitation, the challenges to satisfy these demands are increasing. To follow the previous trend by construction of more, costly desalination plants would be difficult. The challenges can be solved with the introduction of new and modern legislation and institutional actions, and by adopting advanced techniques in water-demand reduction, wastewater reuse enhancement and reduction of water production, treatment and distribution costs. Updated legislation has to be developed to address policy formulation and implementation, guidelines for rational utilization of water resources including desalinated water-use priorities, water ownership, jurisdiction of authorities' responsibilities for controlling utilization, water resources protection, water pricing, beneficial water uses and use permits. Appropriate water legislation enforcement mechanisms must be introduced, including a sufficient the necessary workforce and financial support. Institutional modifications are required to improve coordination of responsibilities and actions among different water agencies. Water tariffs should be increased to reflect the actual value of the water. This will be an incentive to minimize water misuse, to conserve water resources and to reduce the resultant wastewater volumes. This will also help in reducing water-supply costs, and may be used as a financial source to improve the efficiency of operation and maintenance of water-supply projects. The countries of the Peninsula have to consider the introduction of a strong and transparent regulatory framework in order to adopt suitable forms of water-supply privatization. Development of short and long-term water plans on the regional and national levels, using proper techniques for water demand forecasting, is important to achieve realistic and feasible solutions to satisfy water supply and sanitation demands at a reasonable cost.

Conclusions

The Arabian Peninsula countries have experienced major urbanization and industrialization, coupled with great population growth. This has put enormous pressure on local water authorities to satisfy the growing urban water and sanitation demands under the extreme arid conditions and with limited available water resources. Construction of desalination plants on the coasts of the Gulf and Red Sea was a quick but costly solution to the rapid growing urban demand. However, most countries of the Peninsula concentrated on development solutions rather than management. The low water charges served only to enhance the use of water and wastewater production. More attention should be given to new effective technologies in water-demand management, water reuse and conservation. There is a need to improve legal and institutional arrangements for effective water resources management and to define effective water plans, water use priorities and tariffs. Furthermore, it is important to introduce a strong and transparent regulatory framework to reduce the costs of building, operation and maintenance of water and sanitation facilities, and to improve the level of services and billing, leakage and wastewater collection and treatment.

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