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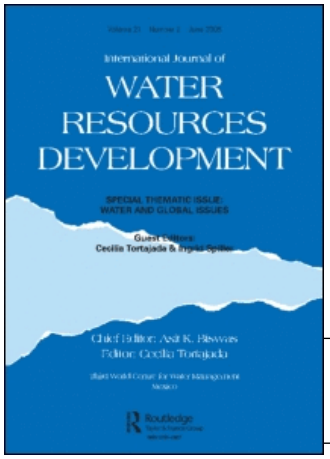

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Water Demand Management and Islamic Water Management Principles: A Case Study

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ABSTRACT *Most of Saudi Arabia is arid and water resources are limited; it has experienced extensive and rapid developments in industrial, agricultural, domestic and construction sectors during the last two decades. Saudi Arabia follows the sacred principles of the Islamic law 'Shari'a', whereby water is considered the common entitlement of all people, and the main component of the sustainability of the nation's life and security. To protect the community of interest which constitutes the traditional basis of Muslim customary water law, the government has control over water resources development, management and planning for the benefit of the whole community. The traditional methods for satisfying the limited water demand in the past have been modified to meet the drastic rise in water demand. Large desalination plants on the Gulf and Red Sea coasts have been constructed to produce sweet drinking water, and thousands of deep and shallow wells have been drilled with government support for agricultural purposes. Specialized water offices for water production, distribution and treatment have been established. Legislation and laws have been developed to organize water-management issues. To protect the interests of the community and its natural resources, several measures were introduced to reduce national water demand and to augment the available water resources. Support for wheat cultivation was reduced to about 25% of the previous level to mimimize irrigation water use. Modern irrigation techniques have been practised to reduce water losses and demand. New water pricing policies, leakage detection and control and promotion of public awareness of water conservation have been practised, significantly during the last decade. The Council of Muslim Leading Scholars gave a pioneering example of the wisdom of Islam by issuing a special Fatwa to regulate the reuse of treated effluents for different purposes. This has promoted wastewater recycling by the public. The Islamic water management principles used in Saudi Arabia can be taken as a model to improve water demand management in other countries.*

Introduction

The Kingdom of Saudi Arabia has an area of about 2.25 million km^2. Most of the country is arid, the available surface and groundwater resources are limited, precipitation rates are low and evaporation is high. The average annual rainfall is less than 150 mm in most of the country. During the last two decades, the Kingdom has experienced comprehensive developments in all sectors coupled with high growth rates in population and living standards. The annual national

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water demand increased from 2352 million cubic metres (MCM) in 1980 to approximately 27 239 MCM in 1990, and in the region of 31 696 MCM in 1992 (Table 3). Saudi Arabia follows the sacred principles of the Muslim law 'Shari'a' in all aspects of life. The fundamentals of Shari'a are: the Holy Koran, the Sunna and Hadiths, the Ijma, Qiyas and customs. The Islamic laws of 'Shari'a' place great importance on water resources, which are considered to be God's gift to mankind, and guaranteed access to water remains free to all in the Muslim community. According to the Holy Qur'an: "…We made from water every living thing" (Surah Al-Anbiyaa, Ayah No. 30); and in Islamic law "water is the common entitlement of all people". In accordance with its responsibility, and to make water available to the whole community, the government has modified the traditional methods for satisfying the limited water demand in the past to meet the drastic rise in water demand. To protect the community of interest that constitutes the traditional basis of customary Islamic water law, several measures were taken to protect the sustainability of water resources. This paper describes the available water resources, growth in water demand and Islamic water management principles in Saudi Arabia.

Development of Legislation and Water Agencies

Abdullah bin 'Umar said, "I heard Allah's Apostle saying, 'All of you are guardians and responsible for your wards and the things under your care. The Imam [i.e. ruler] is the guardian of his subjects and is responsible for them and a man is the guardian of his family and is responsible for them. A woman is the guardian of her husband's house and is responsible for it. A servant is the guardian of his master's belongings and is responsible for them.' I thought that he also said, 'A man is the guardian of his father's property and is responsible for it. All of you are guardians and responsible for your wards and the things under your care'" (Sahih Al-Bukhari Hadith, Vol. 2, No. 18). This Hadith indicates clearly the responsibility of the government to secure for its people their basic needs such as water. Various specialized agencies for water production, distribution and treatment were founded in Saudi Arabia. The Ministry of Agriculture and Water (MAW) was established in 1953, and was assigned the responsibility for water production to satisfy the required water demand in terms of quantity and quality. The Saline Water Conversion Corporation (SWCC) was established as a Ministerial agency under MAW in 1965, then as an independent corporation within MAW in 1974, to be responsible for construction, operation and maintenance of desalination plants for drinking water production. Water and Wastewater Authorities (WWA) were introduced as independent agencies under the Ministry of Rural and Municipal Affairs, to distribute drinking water, and to collect and treat wastewater in the different cities and towns of the Kingdom. Laws, regulations and Fatwas were developed, following the Islamic Laws, to organize water management issues including measures to reduce national water demand and to augment the available water resources.

Assessment of Available Water Resources in Saudi Arabia

Conventional Water Resources (Surface and Groundwater)

The annual runoff in the Kingdom is estimated to be about 2230 MCM. There are

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187 dams of different shapes and sizes, with a total storage capacity of 775 MCM, for groundwater recharge and flood control purposes.

Groundwater is stored in more than 20 layered principal and secondary aquifers of different geological ages (MAW, 1984). The groundwater quality varies between sites and among aquifers. Isotopic analyses showed that the fossil groundwater in the aquifers is 10 000–32 000 thousand years old. The estimated groundwater reserves to a depth of 300 m below ground surface are about 2185 billion cubic metres (BCM) with a total annual recharge of 2762 MCM (Al Alawi & Abdulrazzak, 1994; Dabbagh & Abderrahman, 1997). The renewable groundwater resources are mainly stored in shallow alluvial aquifers and within basalts, which extend mostly through the south-western parts of Saudi Arabia and are of varying thickness and width. These aquifers have an average annual recharge of 1196 MCM.

Non-conventional Water Resources

Desalination water. Thirty-five desalination plants were built to produce potable water from seawater and raw groundwater along the Red Sea Coast and the Arabian Gulf Coast using a Multi Stage Flush (MSF) System and Reverse Osmosis (RO) (Bushnak, 1997). Saudi Arabia is currently the largest desalinated water producer in the world. Annual water production has reached about 719 MCM and capacity will reach approximately 1050 MCM per year by 2000.

Wastewater. It is estimated that about 1000 MCM of wastewater were generated in Saudi Arabia in 1996, and this is expected to increase to about 1500 MCM by the year 2000 (Ishaq & Khan, 1997). About 41% of municipal wastewater is treated. In 1995, about 185 MCM or 18.5% of the treated wastewater was recycled to irrigate agricultural crops and landscape plants or for use in refineries. Treated effluents have been reused to irrigate date palms and forage crops such as alfalfa near Riyadh, and landscaping plants, green-belt trees and grass in municipal parks in Riyadh, Dhahran, Taif, Jubail and other cities in the Kingdom.

Water Demand Management Principles

Several pieces of legislation and laws were adopted to reduce national water demand and to augment the available water resources. According to Islamic laws and custom, human beings are the first priority, followed by animal watering and agricultural purposes; industrial uses come fourth and recreational fifth. The order of the last two purposes was ranked according to the application of Islamic customs, and of reasoning rather than strict doctrine.

Domestic Water Demand Management

With a growth rate of more than 3%, the total population of Saudi Arabia increased from about 7.74 million in 1970 to 11.78 million in 1990 (Table 1). The population is expected to reach 19.315 million in 2010, if the present growth rate continues. Consequently, domestic water demand increased from about 446 MCM in 1980 to about 1563 MCM in 1997, and is expected to reach 2800 MCM in 2010 (Table 2). Given the first priority to secure for the community sufficient

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Table 1. Population growth in the Kingdom of Saudi Arabia (millions)

Year	1970	1990	2000	2010
Population	7.74	11.78	15.553	19.315

Table 2. Growth in domestic water demand in the Kingdom of Saudi Arabia (MCM/year)

Year	1980	1990	1997	2000	2010
Water demands	446	1508	1563	2350	2800

Source: Al-Alawi & Abdulrazzak (1994), Al-Tukhais (1997).

water quantity and suitable quality to satisfy domestic purposes, the MAW drilled hundreds of wells and constructed desalination plants on the Red Sea and the Arabian Gulf coasts, as stated previously. Desalination water production increased from about 540 MCM in 1990 to 795 MCM in 1997 (Table 4). Present desalination production is about 46% of the total domestic demand and was forecast to increase to 1050 MCM by the year 2000. Over US$10 billion were invested in these plants. The desalination unit cost is about US$0.70 or SR2.6 per cubic metre (US$1 = Saudi riyals (SR) 3.751) for a large desalination plant and at the world oil price (Bushnak, 1997). About SR3–4 per cubic metre should be added to the total cost for desalinated water transportation to cities and towns. This means that one cubic metre of desalinated water at house level costs approximately SR5.5–6.6.

Water conservation was emphasized during the early times of Islam. To reduce domestic water demand, several water control and conservation measures were introduced. Examples of these are:

(1) In 1994, water tariffs were introduced to enhance the awareness of the

Table 3. Growth in water use in Saudi Arabia (MCM)

Year	Domestic and industrial	Agricultural	Total
1980	502[a] (21.3%)	1 850[a] (78.7%)	2 352[a]
1990	1 650[a] (6.06%)	25 589[b] (93.94%)	27 239[b]
1992	1 870[a] (5.9%)	29 826[b] (94.1%)	31 696[b]
1997	2 063[a] (11.17%)	16 406[a] (88.83%)	18 469[a]
2000*	2 900[a] (20.57%)	11 200[a] (79.43%)	14 100[a]
2010*	3 600[a] (19.67%)	14 700[a] (80.33%)	18 300[a]

Notes: Values in parentheses are percentages of total. [a] MOP (1990) (losses of 0.3 due to the absence of proper irrigation schedule at farm levels were not considered); [b]Dabbagh & Abderrahman (1997).

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people as to the value of water production. The tariff per cubic metre of potable water is \$0.04 (SR0.15) for the first 100 m^3, \$0.27 (SR1.0) for the second 100 m^3, \$0.53 (SR2.0) for the third 100 m^3, and \$1.07 (SR4.0) for the fourth 100 m^3. The water charges for a medium-sized, middle-class family (six persons) living in a small house with garden (assuming water consumption of about 200 m^3/month) with an average income of SR4000/month are less than \$55/month (SR200/month). The actual costs range between around SR1120 and SR1320. The charges made for water are only a fraction of the actual costs of water production and transportation.

(2) Leakage control measures have been undertaken to minimize water losses from water supply networks.
(3) There has been enhancement of treated wastewater recycling, such as recycling of ablution water in the two Holy mosques at Makkah and Al-Madinah Al-Munawwarah for toilet flushing.
(4) Highly saline water from Wadi Malakan near Mecca has been transported and used instead of desalination water for toilet flushing in the Holy Mosque at Makkah.

Irrigation Water Demand Management

The cultivated areas in the Kingdom increased from fewer than 400 000 ha in 1971 to 1.62 million ha in 1992 (MAW, 1992). The threshold increase in the agricultural areas began after 1979. In accordance with the responsibility to make water available to Saudi citizens for different uses including irrigation purposes, financial support was given to farmers for well drilling and to encourage them to use modern and efficient irrigation systems. Water extension services were also introduced to help the farmers in the proper scheduling of irrigation to avoid any excessive water use. A preliminary assessment of the cost of water production for irrigation from wells with a depth of less than 400 m ranged between SR0.20 and SR0.50 per cubic metre for large irrigation schemes.

In 1992, wheat was grown on 907 309 ha or 56% of the total cultivated area in the Kingdom, and that year's wheat production of 4.25 million tons far exceeded the predicted national demand of 1.22 million tons (MOP, 1990). The trend towards wheat cultivation did not help to diversify agricultural production, and resulted in unnecessary consumption of large volumes of groundwater. The irrigation demand for wheat was 9.9 billion m^3 or 33% of total national irrigation water consumption in 1992. Table 4 shows that in 1997 non-renewable groundwater from shallow and deep aquifers supplied about 90% and 83% of total national water use in Saudi Arabia respectively in 1992 and 1997. The total number of wells drilled increased from about 26 000 in 1982 to more than 80 000 in 1997. Improvement of groundwater management for irrigation, especially for wheat, was essential to maintain the long-term productivity and quality of the aquifers. Realizing the seriousness of this issue, the government, after consultation with leading Islamic scholars, and with specialists in agriculture, economics and water, took several measures and introduced regulations to improve the management of water demand and to protect and conserve water resources:

(1) *Well drilling regulation*: A Muslim is not allowed under Islamic law to cause any harm to others, including his own community. Furthermore, the Prophet

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recognized that the ownership of wells or any other water source requires the ownership of a certain amount of bordering land or Harim, on which it was forbidden to dig a new well so as to avoid any negative impacts on the quality and quantity of the existing well. Following these general Islamic ideals, a Royal Decree was issued in 1980 to regulate well drilling and to protect the aquifers from exploitation and pollution. Special permits should be issued by MAW, in advance, to drill any well or to change its depth. Work should be carried out according to special designs and with supervision from MAW. Penalties were defined for non-observance of this decree by well owners and the drilling companies.

(2) *Reduction in price support to wheat*: In 1993, the government reduced its price support to farmers to a quarter of the previous total wheat area. This was done to reduce wheat production to the level of annual consumption, to encourage farmers to diversify their crop production and to reduce irrigation water consumption. This would lead to a reduction of about 7.422 BCM/year or 25%, assuming 75% reduction in wheat areas. The total area under wheat was reduced by about 325 000 ha between 1992 and 1994. The impact of this reduction was positive in terms of groundwater levels and quality in different wheat areas in the Kingdom. Field measurements of groundwater levels in deep observation wells in a large irrigation scheme in the Eastern province have shown a recovery of about 20–30% of the recorded drawdowns in previous years after reduction of wheat area. Recently, the Ministry of Agriculture and Water announced similar positive impacts on groundwater levels in other regions as a result of modifications in wheat areas.

(3) *Reuse of wastewater effluent for irrigation*: Large quantities of wastewater effluent used to be produced and wasted. Millions of cubic metres of wastewater effluent used to be disposed of without reuse. This was not for technical reasons, but because it was not clear that effluents are pure according to the Islamic viewpoint after removal of impurities by proper treatment. Since Islam is a dynamic religion and can respond to changing conditions, the reuse of wastewater for different purposes to augment and conserve the limited water resources was a major concern of leading Muslim scholars, water scientists, policy makers and decision makers in Saudi Arabia. After lengthy and deep investigations and discussions with scientists and specialists, a special Fatwa (the consensus of opinion of the Council of Ulamah, 'Council of Leading Islamic Scholars [CLIS]' on a given solution to a specific problem at a given time) was issued in 1978 with regard to the conversion of impure wastewater to pure water. The Fatwa postulated that "impure wastewater can be considered as pure water and similar to the original pure water, if its treatment using advanced technical procedures is capable of removing its impurities with regard to taste, colour and smell, as witnessed by honest specialized and knowledgeable experts. Then this cleaned water can be used to remove body impurities and for purifying and drinking. If there are negative impacts on human health from its direct use, then it is better to avoid its use, not because it is impure but to avoid harming human beings. The CLIS prefers to avoid using it for drinking (as far as possible) to protect health and not to contradict human habits" (*Journal of Islamic Research*, 1978). This Fatwa showed the dynamic nature and wisdom of Islamic laws in solving the changing challenges to the Muslim

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Table 4. Water supply in Saudi Arabia in MCM

Water source	1990	1992	1997
Treated wastewater effluents	110[a] (0.70%)	185[a] (0.60%)	185[a] (1%)
Desalination	540[a] (3%)	795[a] (2.55%)	795[a] (4%)
Surface water and shallow aquifers (renewable water)	2 100[a] (13%)	2 140[a] (7%)	2 140[a] (2%)
Groundwater (non-renewable)	24 489[a] (83%)	28 576[a] (90%)	15 376[a] (83%)
Total	27 239[a]	31 696[b]	18 496

Notes: Values in parentheses are percentage of total.[a] MOP (1990) estimate. [b]Dabbagh & Abderrahman (1997).

community. It was an important step in the reuse of wastewater effluent, depending on its degree of treatment, for different purposes such as drinking, ablutions, removal of impurities and for restricted and non-restricted irrigation. The quality of effluent should meet each purpose before reuse. Presently, about 9000 ha near Riyadh are cultivated with date palm and forage crops using about 146 MCM of wastewater effluent. Wastewater is reused for irrigating landscape plants, trees and grass in municipal parks in several cities such as Riyadh, Taif, Jeddah, Dhahran, Dammam and Jubail.

(4) The MAW has considered the introduction of some control measures on water pumping at farm level by water metering to help in minimizing overpumping and water losses.
(5) Possible shifting of some of the fodder and cereal areas from high crop-water consumption zones to lower water requirement areas will result in the saving of considerable quantities of irrigation water consumption.
(6) Enhancement of public knowledge as to the value of water conservation has been undertaken in the news media and in educational institutions.

Industrial Water Demand Management

Although water for industrial purposed constitutes only a small portion of total demand, certain industries require special water quality and the environmental impacts of mismanagement of industrial wastewater represent a major environmental hazard. Industrial water demand increased from about 56 MCM in 1980 to 192 MCM in 1990, and is expected to grow to about 800 MCM in 2010 (Table 5). The growing demands are satisfied mainly from the costly desalination

Table 5. Industrial water demands in the Kingdom of Saudi Arabia (MCM/year)

Year	1980	1990	1997	2000	2010
Water demand	56	192	500	550	800

Source: Al-Alawi & Abdulrazzak (1994), and personal estimate.

processes especially in food industries; and Groundwater satisfies other types of industries. The industrial demands vary among regions of the Kingdom.

In some industrial plants, part of the effluent is recycled. In general, however, a conventional water cycle is practised, whereby a large proportion of the effluent is not recycled. Legislation and measures were introduced to improve industrial water demand management, such as:

(1) Large industrial cities were established in different parts of the Kingdom. Each city contains tens or even hundreds of factories. 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.
(2) A closed water cycle has been introduced to industrial plants to minimize wastewater disposal, to reduce groundwater pumping and to protect the environment. In this approach the wastewater is converted into good quality condensate by evaporation at low temperature under vacuum in a special evaporator. This technology was introduced to large industrial plants in 1995 (Abderrahman, 1997).
(3) There has been enhancement of awareness of effective procedures in wastewater management.

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Conclusions

The following of Islamic Laws in Saudi Arabia helped to develop effective water management to meet the rapid growth in water demand. The measures introduced and legislation in accordance with Islamic Laws helped to accomplish effective water demand management for domestic, agricultural and industrial purposes. The specialized agencies founded for water production and distribution enhanced protection of the interests of the community and its natural resources, reduced national water demand and augmented the available water resources. The introduction of new water pricing policies, leakage detection and control, and the promotion of awareness of water conservation resulted in a further decrease in water requirements. In the agricultural sector, irrigation water demand was lowered by about 25%, by reduction of support for wheat production. The Fatwa that was issued enhanced the reuse of wastewater effluent at the national level. Encouragement by the local agricultural and water authorities to farmers to use modern irrigation systems, the adoption of irrigation scheduling and water-metering approaches resulted in lowering of water demand. The experience of Saudi Arabia shows clearly that Islamic Laws are dynamic and sufficiently reasonable to respond to the changing conditions and challenges of the Islamic nations on vital issues such as water.

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