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WATER CONSERVATION IN THE KINGDOM OF SAUDI ARABIA FOR BETTER ENVIRONMENT: IMPLICATIONS FOR EXTENSION AND EDUCATION

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Abstract

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The kingdom of Saudi Arabia faces an acute water shortage due to arid climate and absence of permanent lakes and rivers. The demand for water is growing substantially and that is being met through the available scarce and dwindling water resources. Ever-increasing imbalances are usually met by increasing water supplies, whereas the concepts of water-demand management have not been given due importance and weightage. Meeting the rapidly rising demand with scarce and depleting resources remains the critical issue. This paper places emphasizes on the urgency of adopting conservation and water-demand management initiatives to maintain demand supply relationship and achieve an acceptable balance between water needs and availability.

The kingdom places emphasis on the shift from supply development to demand management to use of critical and non-renewable water resources efficiently. The article suggests that the water-use-efficiency (WUE) in various sectors can be enhanced and improved in the kingdom. The paper presents an overview of the country's water resources and issues related to water. Some possible conservation and remedial measures particularly in the agricultural sector - the largest and most inefficient user of water have been suggested. The objective of this article is to safeguard and conserve this precious natural resource through environmental friendly technologies for the future generations to come. It is presumed that water resources can be managed on sustainable basis by devising and employing environmental friendly technologies including water conservation measures. The usefulness of these measures can be supplemented through the vibrant and viable extension and education initiatives and capacity building programs.

Key words: water sources, water demand management, environmental friendly technologies, conservation measures, irrigation, awareness creation

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Introduction

Saudi Arabia with an area of 2.15 million km^2 is an arid and water deficit country, with limited fresh water-supplies. The kingdom is a desert like country lying within the continental zone where temperatures are high in summer and low in winter. It is also characterized by low annual rainfall and lacks perennial rivers or permanent bodies of water. The climatic conditions pose a continual challenge, as does the depletion of underground water resources. Due to an acute deficit, water has always been an extremely valuable resource and occupies the prominent and prime position among the natural resources of the kingdom. Although water is a renewable resource, yet its availability is extremely low and to the society. In the situation, there is a tremendous pressure on the existing water resources due to an increase in population, and the rising living standards of the civil society (FAO, 1997; FAO, 2009).

Stress on water resources of kingdom has been further multiplied due to agricultural development and has led to their partial depletion, particularly in the case of non-renewable fossil water which is the main source of fresh water supplies. FAO (2009) reported that the desire to practice desert agriculture elevated the volume of water used for irrigation from about 6.8 km^3 in 1980 to about 21 km^3 in 2006. Further it was noticed that most of the water withdrawn came from fossil; deep aquifers. In the kingdom, some predictions or estimates are made on the presence of water resources that they may not last more than 25 years. Water is a scarce natural resource that ensures human, plant and animal life. This vital and essential resource needs to be managed in a manner that rationalizes its consumption and secures its supply for future generations. The demand for water is increasing quite rapidly against the low and diminishing water resources.

Consequently, it seems imperative to encourage the rational consumption of water and its management by all sectors on a scientific basis to ensure its continued availability and future conservation. Furthermore, there is a need to develop appropriate water quality standards and to enforce rules and regulations relating to these standards. The advanced technologies (such as cloud physics to increase the amount of rain) are needed to develop water resources and measures are to be taken to improve the recharge efficiency of ground water (PMSAUN, 2009). In this article, an attempt has been made to review the available water resources of the country and possibly tailor the measures to be adopted to consume them efficiently and conserve this precious resource with the national spirit.

A Review of the Water Resources of the Kingdom

The water resources in the Kingdom are divided into surface and underground deposits. Water collected through rainfall (surface water) is estimated to be about 2045 million cubic meters (MCM) per year. Depending upon rainfall, ground water is present in the basement crystalline rocks with an estimate of about 1.5 million cubic meters. The thickness of these rocks is about 500 meters. The production of the desalinated water reaches 740.52 million American Gallons daily. In the kingdom, about 1.5 million cubic meters treated sewage water per day is also available, in addition about 32 million cubic meters per day the treated agricultural waste water is diverted to useful uses (UNCCD 2000). The Kingdom extracts its water from the following main sources:

Surface water is available with an estimate of about 2045 million cubic meters (MCM) per year comes from the rainfall, and is found predominantly in the west and south-west of the country. In 1985, surface water provided 10% of the kingdom's supply. While reporting on water resources, FAO (2009) noted that total renewable surface water resources could be about 2.2 km^3/year in the kingdom of Saudi

Arabia. Abderrahman, (2009) reports that the annual runoff is estimated about 2230 MCM in the kingdom.

Ground water is found in the area of the basement rocks and the thickness of these rocks could be about 500 m. Ground water is held in aquifers, some of which are naturally replenished, while others are non-renewable. In 1985, ground water provided 84% of the Kingdom's supply but it is noteworthy that most of this water was drawn from non-renewable aquifers.

Similarly, Abderrahman, (2009) also reported that the renewable groundwater resources were mainly stored in shallow alluvial aquifers and in basalt layers of varying thickness and width, and these aquifers mostly prevail in the southwest of the kingdom. They are in a position to store some 84 billion cubic metres with an average annual recharge of 1196 MCM. More than twenty layered principal and secondary aquifers of different geological ages store groundwater (MAW 1984), and the quality of the ground-water varies at various sites and aquifers. FAO (2009) also maintains that total groundwater reserves (including) fossil groundwater) have been estimated to 500 km^3. About 340 km^3 out of this 500 km^3 is drawn at an extremely high cost by the kingdom of Saudi Arabia. Estimates on available ground waters seem quite encouraging to meet the growing needs of the population of the kingdom (FAO, 2009).

Based on the isotopic analyses scientists believe that the fossil groundwater in these aquifers is ten to thirty-two thousand years old. At the depth of three hundred metres below ground surface about 2185 billion cubic metres groundwater is available with a total annual recharge of 2762 MCM (Al Alawi and Abdulrazzak, 1994; Dabbagh and Abderrahman, 1997).

Desalinated seawater is the source of water production in which kingdom has emerged today as the world leader. Desalination technology, which also produces electricity, has reached an advanced stage of technology in the Kingdom and, by 1985; this source was providing 5% of the Kingdom's supply. SIWI (2009) reports that desalinated plants are providing more than 70 per cent of the required drinking water.

FAO (2009) reports that by 2004, there were only 30 desalination and power plants in the country and in 2006, about 1.03 km^3 of desalinated water were produced. The total length of about 4156 km pipeline desalinated water is transmitted to various cities and the capacity of desalinated water reservoirs reached to 9.38 MCM. The water produced, is being used for municipal purposes.

As reported by Abderrahman (2009) that some 35 desalination plants have been built, with the cost of about 10 billion dollars, to produce potable water. By employing multistage flush system and reverse osmosis techniques, brackish sea water and raw groundwater from the Red Sea coast and the Arabian Gulf coast are converted into drinkable forms (Bushnak, 1997). He further noted these technologies and facilities helped Saudi Arabia becoming the largest producer of desalinized water in the world. On an average about 1050 MCM desalinated water was produced only in the year 2000.

According to FAO (2009) the quantities of desalinated water produced meet some 48 percent of the requirements of municipal uses. Although the cost of water associated with desalination units remains very high yet it is made available to the general public at a highly subsidised rate. Abderrahman (2009) reported that the total water cost for one cubic metre of desalinized water is about SR 5.5 - 6.6 at the door step of the consumers. Still large-scale desalination plants were in a position to meet the 46 per cent of the household requirements and domestic demand for water.

Reclaimed wastewater is obtained by treating agricultural waste water and it estimated to be about 32 MCM per day. It is a source of water which is still in its early stages but offers a considerable potential for further expansion. Similarly, recycling of purified sewage water for agricultural and industrial use is taking place and the first project in this respect was established in the city of Riyadh and saves about 200 000 m^3 of purified water a day. According to Abderrahman (2009), it is estimated that about 1000 MCM of wastewater were generated in the country in 1996, and about 1500 MCM in the year 2000 (Ishaq and Khan, 1997). About 41 per cent of municipal wastewater is treated, and in 1997, about 185 MCM or 18.5 per cent of the treated wastewater was recycled for irrigating agricultural crops and landscape plants and for using in the refineries (Abderrahman, 2009).

In addition, FAO (2009) reports that total treated wastewater reached almost 548 MCM, of which 123 MCM were reused. By the year 2003, some 70 sewage treatment plants were working and in operation. No doubt, the idea is new and the use of treated waste water still did not hold enough ground as only 166 MCM were being used in 2006, but it has got a very promising future in the kingdom for its multiple and beneficial uses. However, presently non-edible crops are irrigated with treated waste water. Different landscapes, gardens, parks also receive their irrigations with treated waste water, and for industrial cooling, they are equally good (FAO, 1997).

Artesian Wells are being used for irrigating agricultural crops, human consumption and drinking purposes. To meet the water requirements of its population, more than 40 810 artesian wells in addition to 52 327 traditional wells have been drilled (U.S. Department of Energy, 2002).

Dams collect rain and flood waters quite efficiently. In order to utilize these waters for useful purposes, the building of dams at various locations is of significant importance. Before 1975, there were only 16 dams in the kingdom; the number increased to 190 by 1999 and 223 by 2004, with the collective storage capacity of 836.6 MCM (FAO, 2009). Today, there are more than 237 dams, with a total storage capacity of 775 MCM, for groundwater recharge and flood control. King Fahd Dam, the biggest one in Bisha Valley with a capacity of 325 MCM and was built in 1997 (U.S. Department of Energy, 2002). These dams store flood and storm water and in turn dams increase subterranean water reserves and enhance the availability of potable water. They protect the vegetation and plantations and some villages against the fast flows of flood waters as sudden torrential rises used to be the big threats in the past.

The Development and Growth Means an Increase in Water Demand

The available surface water and groundwater resources are limited, precipitation rates are low, evaporation rates are high, and most part of the Kingdom lies in arid regions. All these factors make the kingdom a water shortage and deficit state. An average annual rainfall is less than 150 mm in most parts of the country (FAO, 2009). Due to the comprehensive development realized in all sectors, today the annual national water demand in the kingdom has exceeded 30 000 MCM (Abderrahman, 2009) as revealed in Tables 1 and 2. In the kingdom supply aspect received attention, whereas demand management remained un-noticed, despite of its improved and enhanced potential benefits.

Conservation Measures

Water Demand Management

At present the concept of Water Demand Management (WDM) is slowly gaining recognition and popularity as an essential complement to supply management if fresh water is to be used in a sustainable manner (Brooks, 2009). While WDM showed many economic benefits by increasing efficiency as well as, in

Table 1
Growth of water use in Saudi Arabia, 1980–2010, million m^3

Year	Domestic and industrial sectors (MCM)	%	Agricultural sector (MCM)	%	Total
1980	502	21.3	1850	78.7	2352
1990	1650	6.06	25 589	93.94	27 239
1992	1870	5.9	29 826	94.1	31 696
1997	2063	11.17	16 406	88.83	18 469
2000	2900	20.57	11 200	79.43	14 100
2010	3600	19.67	14 700	80.33	18 300

Sources: MOP 1990; Dabbagh and Abderrahman, 1997 (Agricultural and Total use, 1990 and 1992); Abderrahman, 2009

Table 2
Water supply in Saudi Arabia, 1990–1997, million m^3

	1990	%[a]	1992	%[a]	1997	%[a]
Surface water and shallow aquifers (renewable)	2100	13	2140	7	2140	12
Groundwater(non-renewable)	24 489	83	28 576	90	15 376	83
Desalination	540	3	795	2	795	4
Treated wastewater effluents	110	0.7	185	0.6	185	1
Total	**27 239**		**31 696**		**18 496**	**100**

Sources: MOP 1990 estimate; Dabbagh and Abderrahman, 1997 (1992 total).

[a] Percentages do not add to 100 due to rounding up the figures

many cases, greater equity, reduced environmental damage, and helped increasing greater public participation. Water demand management can be defined as any method -- whether technical, economic, administrative, financial or social – is capable of accomplishing one (or more) of the following five components:

- Reduce the quantity or quality of water required to accomplish a certain and specific task;
- Adjust the nature of the task or the way it is undertaken so that it can be accomplished with less water or with lower quality water;
- Reduce the loss in quantity or quality of water as it flows from source through use to disposal;
- Shift the timing of use from peak to off-peak periods;
- Increase the ability of the water system to continue to serve the communities when water availability is low and at times of shortage of water.

Some of the conservation measures taken so far include the following:

- In 1994, water tariffs were introduced to enhance the awareness on the value of water among the consumers.
- Measures have been undertaken to reduce the water leakage losses from the water supply networks.
- Programs on treated wastewater recycling

have been designed, introduced and launched;

- In the toilet flushing at the Holy Mosque at Makka, highly saline water from Wadi Malakan near Makka is being used instead of using the costly desalinated water (Abderrahman, 2009).
- Initiatives on reuse of wastewater effluents for irrigation purposes have been taken;
- Landscape plants, trees, and grass in municipal parks receive their irrigations through the reusing of wastewaters.
- The kingdom also plans of installing water meters on the farm pumps to minimize over pumping and water losses.

To minimize industrial water demand, to maximize wastewater recycling and to protect the environment, the government has established large industrial cities in numerous parts of the kingdom. Each city comprises of hundreds and thousands of factories and they produce thousands of gallons of waste water. Industrial wastewater is collected, treated, and recycled within each city at the plant level for using it for industrial uses and irrigation purposes. The industrial cities have set certain standards and specifications for the quality of the wastewater to be collected from factories (Abderrahman, 1997; 2009).

Recommendations on Water Conservation

FAO (2009) has offered the whole set of recommendations for managing water for agriculture; however, a brief sketch is presented as under:

- There is a need for the strict policies for use of water and adoption of conservation measures.
- Agricultural sector is the biggest consumer of water (88%) and to keep its usage minimum better and improved irrigation methods and environmental friendly farming technologies are needed.
- To help farmers to grow drought resistant/tolerant varieties crops and trees, continued research support is needed. Research initiatives on exploring new irrigation methods and improving the presently available irrigation methods to use the limited water resources efficiently and effectively are needed.
- There is a need to create awareness among the users in both rural and urban areas, persuading the users to adopt conservation measures and environmental friendly technologies.
- Training programs for the trainers and the users on the water demand management and its conservation should be arranged.
- The initiatives on the reuse of wastewater effluents especially for irrigation have been encouraged and now millions of cubic metres of treated effluents have become available for this purpose. Similarly, recycling of treated industrial wastewater is another appreciable initiative, and has been implemented by various industrial plants.
- Surface irrigation systems should be replaced by drip, sprinkler irrigation and micro-irrigation systems.
- Promote the cultivation of crops with lower water requirements. There is a need of shifting of some of the fodder and cereals areas from high water consumption zones to lower water consumption zones.
- Encourage farmers having water meters at the farm level to control of pumping of water.
- The initiatives taken by the kingdom on water demand management have been successful in satisfying growing water needs and protecting water resources. This demonstrates that the programs launched by the state on the most vital and pressing issue of water are sufficiently dynamic, flexible, and reasonable enough to solve the challenges faced by the nation. Extension professionals need to promote and popularize them among the masses.
- It is stressed that the available environmental friendly technologies on the wise use of water be enlisted and be known to the end users through extension and education programs.

- The state regulations on the use of water, reduction in domestic water demand by the introduction of new water pricing policies, leakage detection and all other control measures that could conserve water must be applied with letter and spirit.
- Concerted efforts should be made by all the stake-holders working with the public on enhancing public awareness on the value of water.

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