Desalination and Water Treatment
www.deswater.com
51 (2013) 67–74
January
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doi: 10.1080/19443994.2012.704725
Taylor & Francis
Taylor & Francis Group

Water security and stability in the Kingdom of Bahrain

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Received 2 March 2012; Accepted 15 June 2012

ABSTRACT

Water security has been recently defined as the capacity of a population on ensuring that they continue to have access to safe and properly sanitised potable water. Today, water security issues encompass increasing concerns arising from population growth, drought, climate change, oscillations between "El Nino" and "La Nina" effects, urbanisation, increasing salinity (e.g. the Arabian Gulf region), upstream pollution (for rivers), over-allocation of water licences by government agencies and over-utilisation of groundwater from artesian basins. All these distresses combined have resulted in a rapid decline in water security for many parts of the world, triggering off impacts of suffering to regions, states and countries, while tensions tend to exist between "upstream" and "downstream" users of water within individual jurisdictions (as throughout history, there has been much conflict over the use of water from rivers (such as the Nile, the Tigris and the Euphrates rivers)). In modern days, in many parts of the world, water security is mostly sought by implementing water desalination, pipelines between sources and users, water licences with different security levels and (sadly to say) war; while water allocation between competing users is increasingly determined by application of market-based pricing for either water licences or actual water. As water desalination is a crucial topic on the water security agenda worldwide, this paper shall examine interrelated issues concerning water management and water privatisation (global and in the Kingdom of Bahrain, with some focus on the preparedness of Kingdom of Bahrain for emergency situations), and shall briefly underline the countries and regions of the world that are suffering most from water stress (like North Africa, Middle East, Central Asia, China, Chile, South Africa and Australia).

Keywords: Access to safe and sanitised potable water; Population growth; Drought; Climate change; Urbanisation; Over-utilisation of groundwater from artesian basins; Water security; Water desalination; Pipelines; Water management; Water privatisation

1. Overview

Until the early 1950s, the Kingdom of Bahrain enjoyed the abundance of freshwater through natural springs. However, the demand grew as a result of the increase in population and the rapid construction boom. Consequently, the groundwater abstraction significantly increased in the late 1970s. During this period, the groundwater abstraction for irrigation needs also increased significantly. This trend

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Presented at the International Conference on Desalination for the Environment, Clean Water and Energy, European Desalination Society, 23–26 April 2012, Barcelona, Spain

continued in the 1980s and 1990s, as a result of which the piezometric level of groundwater began to fall, causing the intrusion of seawater into the aquifer. The collective result was deterioration in groundwater quality (in terms of salinity).

Various options were considered to overcome this critical situation. Construction of desalination plants (multi–stage flash [MSF] and reverse osmosis [RO]) with sufficient capacity was accepted as the best solution and limited the abstraction of groundwater to the minimum for blending purposes only.

The demand for water, however, continued to increase at a much faster rate than the installed desalination plants' capacity, compelling the need for continued abstraction of large quantities of groundwater. To arrest this enormously increasing trend, the Council of Ministers in its session of 19 May 1994 approved the recommendation for a daily consumption ceiling of 70 MIGD. With this, the maximum groundwater abstraction was limited to about 33 MIGD [1].

In 1975, at that time, the Ministry of Electricity and Water (now is the Electricity and Water Authority) planned to introduce metering systems on demotic supplies that played an important role in reducing the consumption and enabling of having a more accurate assessment of wastage.

In the past few years, the idea of water conservation started in the Kingdom of Bahrain in order to contain the reduction in daily supply and prevent wastage. Some technical measures were undertaken to regulate pressure in the distribution system and limit the hours of supply. Side by side, the leaking service connections were replaced to prevent leakage in the service connections. A Conservation Department was also established to meet this growing need under regulated criteria.

As we all perceive, water is essential for all aspects of life, and managing water is a challenging and demanding task, particularly in shared water basins.

Realising that achieving water security in the Kingdom of Bahrain is not an option but it is by far a necessity. Oil-rich countries are striving to find new environments, friendly and more economical ways of producing freshwater.

Rapid modernisation, combined with other factors has led freshwater sources to dwindle and fossil fuel-supported desalinations to become more expensive in the GCC Countries.

The situation in the Kingdom of Bahrain and the GCC Countries is worsening due to several factors, including population increase, industrial development, commercial growth, tourism projects and wastages.

Climate change caused by global warming could also affect water resources where it will elevate global temperatures, which could change the world's rainfall patterns.

2. Is desalination the answer for water security in the Kingdom of Bahrain?

The Kingdom of Bahrain needs large quantities of water. Owing to scarcity of underground freshwaters, one obvious source would be the sea. It seems so reasonable to have water desalination as a vital option when a country is short of freshwater.

Several different methods and techniques can be applied to desalinate seawater. The technologies that are used in the Kingdom of Bahrain are: MSF, Brackish Water Reverse Osmosis (BWRO), Seawater Reverse Osmosis (SWRO) and Multi–Effect Distillation (MED). The main setback to desalinated water processes is the usage of large amount of costly energy.

2.1. Definition

Water security is the capacity of a population to ensure that they continue to have access to sufficient quantities of potable water with adequate sanitation. It is an increasing concern arising from population growth, drought, climate change, urbanisation, salinity, upstream pollution, over-allocation of water licenses by government agencies and over-utilisation of groundwater from artesian basins. Water security is rapidly declining in many parts of the world.

Water security is sometimes sought by implementing water desalination, pipelines between sources and users and water licensees with different security levels.

Moreover, water security is a water treatment technology dedicated to providing solutions to the world's most challenging water quality problems (Fig. 1) [2].

2.2. Implementation

Water demand in the Kingdom of Bahrain has dramatically augmented from approximately 12 MIGD in 1970 to about 27 MIGD in 1980 and to about 62 MIGD in 1990. By the end of 2009, demand rocketed to 142 MIGD. The water consumption was approximately 404 L per head per day (89 gallon per head per day) on an average throughout the year in 1970 [3].

Previous records reveal that the rate of growth of demand had been in the order of 4% per annum. In 1995, the per capita consumption reaches to 126 MIGD. The Electricity and Water Authority worked so hard to reduce this figure to 113 MIGD in 2009.

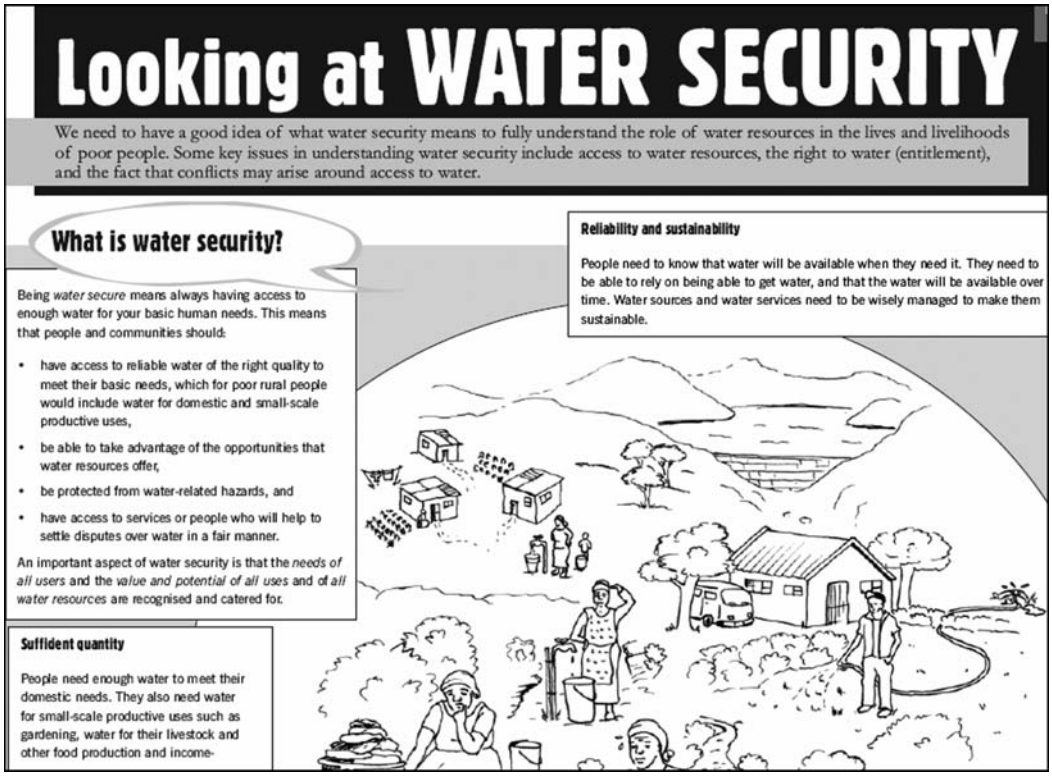

Fig. 1. Water Security for the Stability of Communities Lifestyle [2].

This increase in water demand was a natural consequence of population growth coupled with the economical, sociological and construction activities boom associated with the high rise in oil revenues in the 1970s and 1980s.

This inevitably led to a requirement to mix larger volumes of desalinated water to achieve a suitable potable supply standard, the alternative being that the supply reaching the consumer will be increasingly saline.

Today, groundwater studies concluded that unless the abstraction is limited to 5 MIGD, the freshwater aquifer would be lost by the turn of the century.

3. Water security history in the Kingdom of Bahrain

Sitra MSF Power and Water Station was the first desalination plant, commissioned in 1975 with an initial capacity of 5 MIGD. Later on, the capacity of this facility was increased from 5 to 25 MIGD by the year 1984 [3].

This was followed by the Ras Abu Jarjur Brackish water Reverse Osmosis Desalination Plant which desalinates the brackish groundwater from "Aquifers C", with an installed capacity of 10 MIGD. Later, the plant capacity was increased to 12.5 MIGD, and later on in 2005 the plant underwent Expansion Works wherein two more RO Units were added to the eight thereby increasing the capacity to 16.5 MIGD [3].

The third plant is the Addur SWRO Desalination Plant, which was built with a capacity of 10 MIGD. Unlike Ras Abu Jarjur Plant, this is Seawater Reverse Osmosis Plant where the average daily production reaches 6–6.5 MIGD owing to several process problems [3].

In 1999, the Hidd Power and Water Station (Phase I, MSF technology) was constructed with a capacity of 30 MIGD. In 2008, this capacity was maximised to 90 MIGD (Phase III, MED technology) [3].

The Government of the Kingdom of Bahrain has introduced new privatisation system and invests in the water sector where an agreement made with Alba Plant to supply the National network with 9 MIGD.

Table 1 comprises general information on the water desalination status (from the point of view of the water security situation) in the Kingdom of Bahrain [3].

Each of these water desalination facilities has been located at what appears to have been traditionally named as watering–places, perhaps initially only serving the area in their immediate vicinity; however, over the years, their respective distribution networks

Table 1
General information on water desalination in the Kingdom of Bahrain [3]

Water plant/station	Commissioning date	Installed capacity MIGD	Desalination process/ technology
Sitra power and Water Station	1975	25	Seawater MSF
Ras Abu Jarjur Brackish RO desalination plant	1984	12.5	Ground water (Aquifer C) RO
	2005 (expansion)	4 (added) [16.4 (overall)]	
Hidd power and water station (HPC, private)	1999 (Phase I)	30	Seawater MSF
	2007 (Phase III–1)	12 (added)	Seawater MED
	2008 (Phase III–2)	48 (added) [90 (overall)]	
Addur SWRO desalination plant	1990	10 [6.5–6, current capacity]	SWRO
ALBA Desalination Plant	2004	9 (agreed) [7–8 (delivered)]	Seawater MED
Al Dur power and water company (ADPWC, IWPP)	2012 (commissioned: February 2012)	48 (design) [15 (delivered)]	Seawater RO
Maximum ground water abstraction		25 MIGD	
Total water production in the Kingdom of Bahrain		≈184.5 MIGD	

had been presumably extended and combined to form two basic reticulation system one serving rural areas and one serving urban areas. The water system extend where it is linked together so that supplies from one area can be used to augment the other whenever necessary.

4. Bacteriological content of boreholes

There are a few boreholes in the Kingdom of Bahrain that contain microbial contaminants like Total Coliform and E. Coliform Bacteria, while a few others that contain only Total Coliform Bacteria.

Boreholes contaminated with Total Coliform and E. Coliform Bacteria are kept isolated to protect the supply network; on the other hand, boreholes with only Total Coliform Bacteria are in use with pre-chlorination so as to meet the supply–demand with sanitised condition.

The bacteriological content of the major borehole in the Kingdom of Bahrain is shown in Table 2 [1].

5. Groundwater quality and abstraction rates

Still the average groundwater abstraction in 2009 continued to be high in the range of 22 MIGD, which was far more than the ceiling of 5 MIGD fixed for domestic use. Fig. 2 shows the annual rate of groundwater abstraction from 1980 to 2008 for the Kingdom of Bahrain [1].

To contain the reduction in daily supply and the abstraction of groundwater and so as to prevent wastage, Water Distribution Directorate (WDD) took somewhat rigorous technical and legislative measures (where the technical measures included the regulation of pressure in the distribution system and limiting the hours of supply).

Side by side, the leaking service connections were replaced to prevent or minimise leakages in the system. Systematic waste detection and remedial measures were also undertaken simultaneously to prevent loss in the distribution systems. Furthermore, water saving measures and treated sewage effluent re-use will assist in re-dressing this imbalance.

In general, the quality of water is judged on the basis of standards, which are investigated by bacteriological and chemical analysis of suitable samples carried out under certain prescribed conditions in accordance with WHO standards.

The quality of groundwater varies from borehole to borehole, but it was always very hard and with high salinity. The total dissolved solid (TDS) content being in the range of 2,500–3,200 mg/l (ppm). The groundwater quality has shown some improvement following Hidd Power Company (HPC) had potabilsed their desalinated water, where the TDS drop to an average of below 600 mg/l (as indicated by Fig. 3) [1].

Most of the areas in the Kingdom of Bahrain are supplied with treated potable water, while the

Table 2
Bacteriological content of the major borehole in the Kingdom of Bahrain [1]

Boreholes details			Area					Grand total
			Manama	Hamala	Northern Villages	Muharraq	Sitra	
Isolated	Contaminated with E. Coliform bacteria	No.	2	1	6	3	0	12
		lps	70	45	195	60	0	370
Un-Isolated	Contaminated with total Coliform bacteria	No.	6	7	4	2	0	19
		lps	170	280	160	90	0	700
	Not contaminated	No.	17	12	8	12	1	50
		lps	690	500	350	310	25	1,875
Total		No.	25	20	18	17	1	81
		lps	930	825	705	460	25	2,945

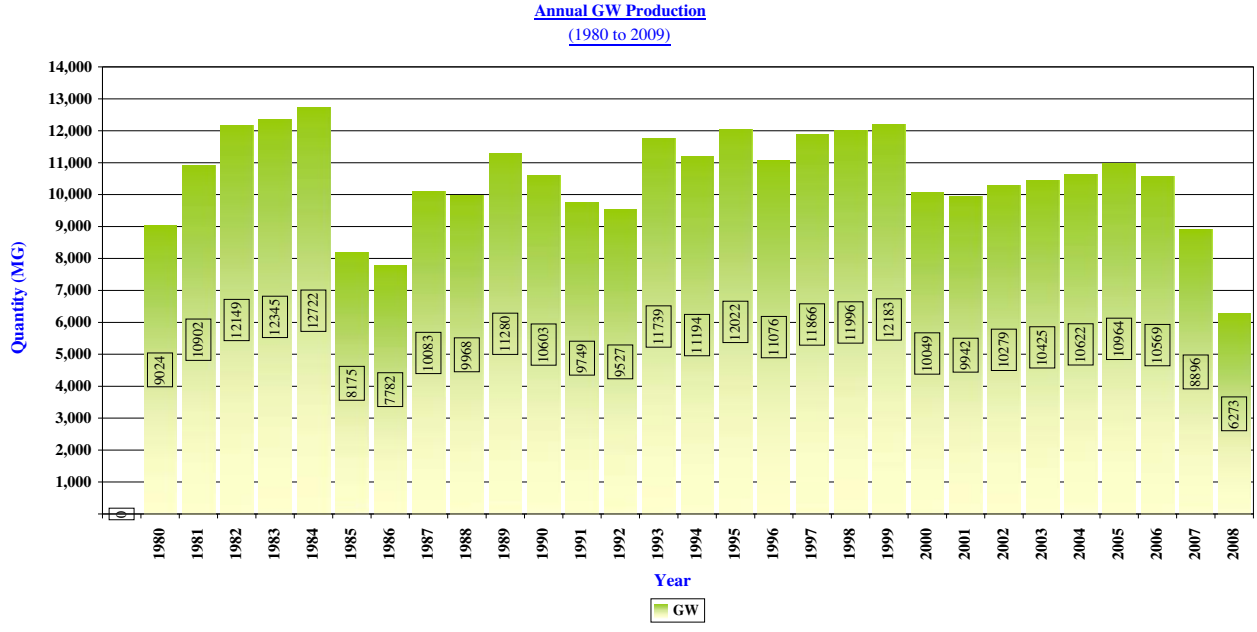

Fig. 2. The annual groundwater abstraction rate from 1980 to 2008 for the Kingdom of Bahrain [1].

potable water TDS supplied to West Riffa'a and Hamad Town areas sometimes cross the limit of 1,000 mg/l, however, this is expected to be improved following the additional desalination capacity when the new Al Dur IWPP comes on stream (by August 2011).

The below chart (Fig. 4 [4]) clarifies how relying on the groundwater abstraction for domestic use in the Kingdom of Bahrain has been reduced with a parallel introduction of potable water to provide water security since 1980 until 2009.

6. Storage facilities

Water storage tanks play a vital role in participating to provide water security system in the Kingdom of Bahrain so as to ensure a continues supply to the people during breakdowns and emergency situations where it will count as an alternative supply to the people during the water plants' failures.

Currently, the total storage capacity in the Kingdom of Bahrain (including elevated towers) is nearly 293.5 MIG, which represents 2 days of emergency storage supply [3].

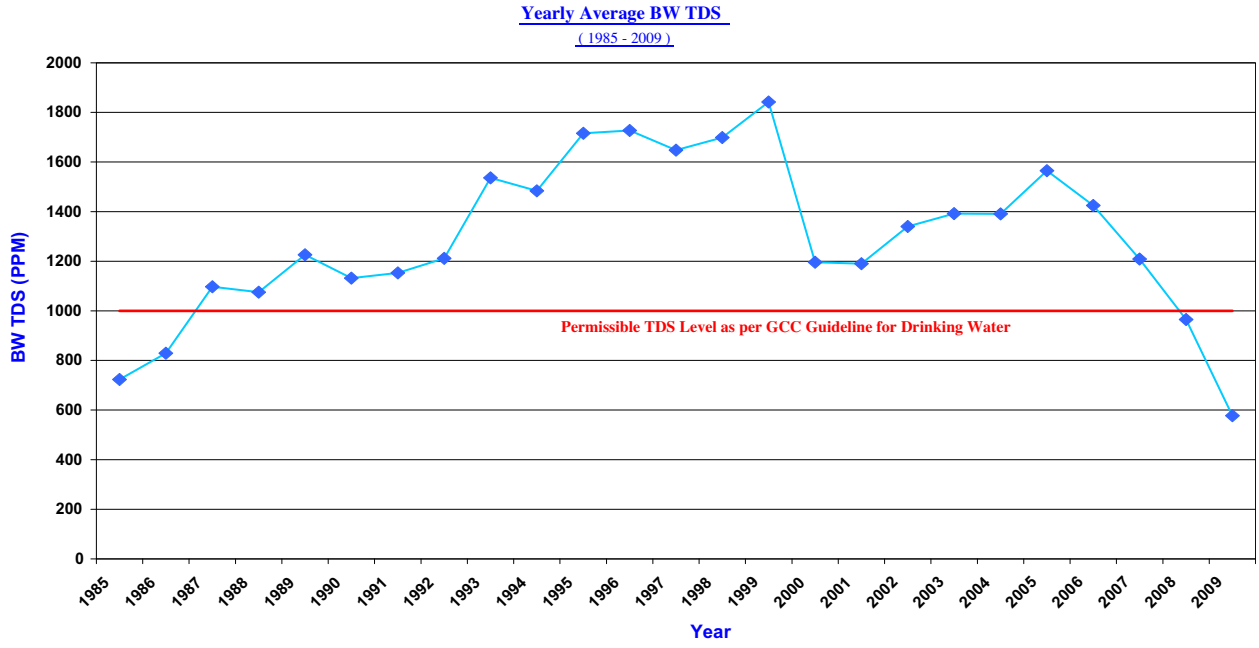

Fig. 3. Trend of annual groundwater quality variations from 1985 to 2009 in the Kingdom of Bahrain [1].

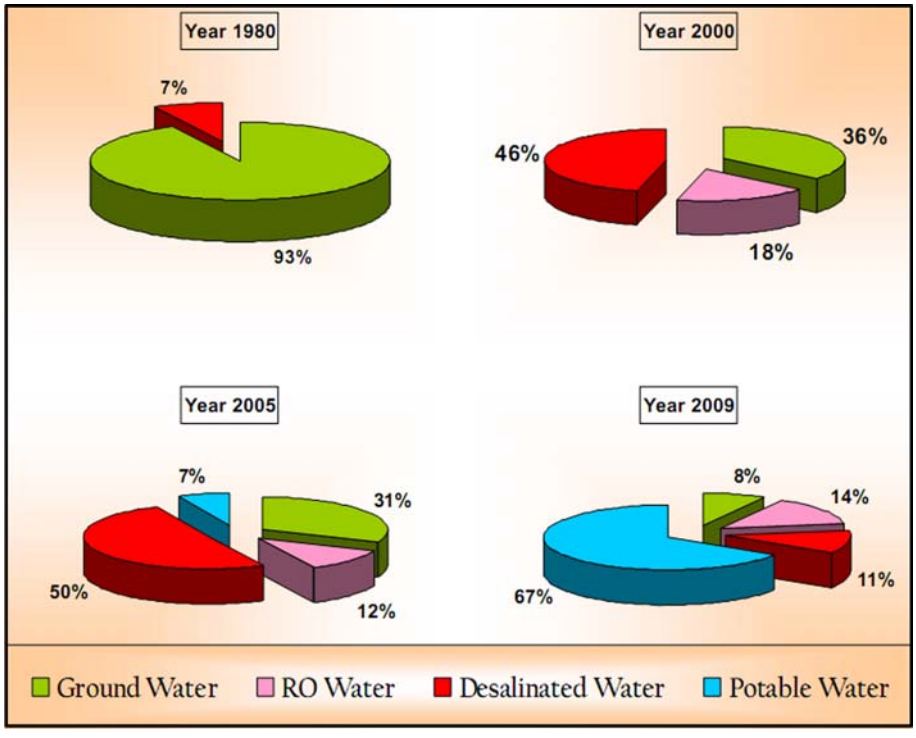

Fig. 4. An illustration of the changes in the various water segments availability and usage in the Kingdom of Bahrain since 1980 until 2009 [4].

The growth of storage capacity in the Kingdom of Bahrain water system started with 10.67 MIG in 1980 until it has reached to this capacity (i.e. 293.5 MIG) in 2009 by means of constructing many ground storage

tanks of different capacities along with elevated towers.

7. Does the water system in the Kingdom of Bahrain provide security to the people?

The Kingdom of Bahrain could face a potential security crisis unless strategic measures are taken to protect the diminishing water resources:

(1) The struggle for limited resources and growing demand and raising population levels is likely to end in critical situation.
(2) We have to work on several fronts to try and manage the demand. Demand management is an issue and we should work on reducing or eliminating the water leaks in our networks.
(3) The Kingdom of Bahrain desalinates 144.5 MIGD of seawater along with 25 MIGD of brackish groundwater for the domestic, commercial, industrial and irrigation purposes.
(4) The Kingdom of Bahrain is poor in natural water resources and suffers from very low rates of rainfall where most of the boreholes are deteriorated and cannot be used under normal conditions. Yes, it was used under emergency conditions to provide water supply to the people during breakdowns.
(5) Ninety percent of water demand in the Kingdom of Bahrain has been secured via desalination process.

8. Is it reliable to depend on the above technology to achieve water security in the Kingdom of Bahrain?

(1) This big question is not only applicable for Kingdom of Bahrain but also touches on all the GCC integrated networks, as all system and machineries that are used in the water production are imported from foreign countries.
(2) On this issue, we have to think about the security of procuring all the required equipment and machineries for the water production plants to ensure continuity of running the machines to desalinate the seawater in order to be in the safe side.
(3) On the other hand, the fuel used in running water production plants must be ensured too, as well as searching for another energy technology (such as renewable energy). Water and electricity production plants in the Kingdom of Bahrain utilise huge amount of natural gas, which may result in its storage getting down.
(4) Along the years, the government of the Kingdom of Bahrain has invested billions of Bahraini Dinars in the water sector so as to ensure water security for domestic use as a first priority more than any other purpose.
(5) The Kingdom of Bahrain, similar to its neighbouring GCC Countries, focus on water technologies research processes from the economical point of view to provide the required quantity and quality for the people as all aquifer–reservoirs have become poor in freshwater [5].
(6) The water situation in the kingdom of Bahrain is regaining a high priority from the Government where His Royal Highness Shaikh Khalifa Bin Salman Al Khalifa issued a resolution to form a Water Resources Council in the Kingdom of Bahrain responsible to save and develop water resources to ensure sustainability and continuity to meet comprehensive developments and protect the future generation water rights.
(7) The Water Resources Council will coordinate and manage water resources via Integrated National Scheme for Water to achieve the water strategy balance between supply and demand according to the Bahrain 2030 Economic Vision.

9. Conclusions and recommendations

Any National Plan devised for Water Security in any community has to contain many of issues addressed below:

(1) New approach design to ensure satisfying future forecasted demand for all the Governorates of the Kingdom of Bahrain based on 15 years master plan [5].
(2) Studying new renewable alternative energy sources to produce desalinated water by using solar or wind energy technologies.
(3) All GCC water experts stress on the need of applying water security in their countries on the short- and the long-term plans to satisfy the requirements and achieve the safe level of water security [5].
(4) Create a water fund security to motivate the gaining of knowledge and water techniques, which support the national efforts to power and promote projects so as to maintain strategic water storage [6].
(5) Waste water treatment projects must be fully utilised at higher level in order to reduce the waste and high energy used to produce the potable water. This treated water can be used for irriga-

tion, aquifer recharges, industrial and many other processes that do not require potable-quality water.

(6) Support the national initiatives in issuing the legislation and policies to ensure independent, continuous manage and financing subsidy to the water fund security in establishing water research institute as well as societies for water science and technology [7].

(7) All related organisation and authorities are required to provide studies and research related to water security (like Universities, Research Centres, Geologic Authority and Ministry of Agriculture) to provide full view of the required water security in the Kingdom of Bahrain [8].

(8) Create a Data Bank ensuring a continuous updating of all water resources, machinery and equipment used in water production, water consumption, progress of water conservation programmes and activities and develop conventional and unconventional capabilities in order to benefit from each single drop of water [9].

(9) Water conservation programmes must be fully activated to control water demand and provide all tools to help manage the water demand via different activities and events [9].

(10) Generate new integrated strategy to balance food and water security (i.e. achieve food security in a way that will not affect the water security) [10].

(11) Water resources should be managed from the perspective of a holistic situation and integrative vision that require community concerned-efforts to legalise and conservative all types of water consumption by legislative technical means, irrigation consumption control by using moderns irrigations methods [11] which match with specifications and standards that enjoy water security in accordance with the approved development plans and vision of the Kingdom of Bahrain 2030 Vision.

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