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Potential for Implementation of Water Demand Management in Bahrain

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ABSTRACT: Water is now considered a scarce but essential resource that should be managed in an integrated manner. Current urban water management concepts and practices cannot adequately respond to these requirements. The traditional approaches of resource handling are now considered as unsustainable. Water Demand Management (WDM) is a new approach that aims at influencing demand and thus improving distribution efficiency. There is a need to change the way that water resources are managed. In order to maintain sustainability, water Demand Management (WDM) application tools are required in addition to supply management,

This paper presents a review of the currently existing water demand management measures such as economic, technical and social awareness in Bahrain. It focuses on the case studies of the development of alternative water demand management carried out in Bahrain—a fully urbanized, country by way of leakage control, water tariff, and water conservation.

The paper also looks into scope of modifying age-old conservation practices by way of educating the public at the grass root level like schools, mosques and other social places and public forums.

INTRODUCTION/BACKGROUND

Water resources in Kingdom of Bahrain are scarce and the demands are outstripping the supply. Bahrain is characterized by a harsh desert environment with no surface water (rivers or lakes). Bahrain receives an average annual precipitation of less than 100 mm. The situation will be aggravated in the future in view of the limited water resources and the growing demands from different users. Electricity and Water Authority (EWA) recognizes that water is a critical issue for Bahrain's development as it relies on non-conventional water resources (desalination and reclaimed wastewater) and is currently increasing its reliance on this mode of water supply as the population grows.

Yet the cost of exploiting the country's remaining fossil groundwater is rising rapidly. Unless the resources are effectively used and managed, it will be extremely difficult for the EWA to meet the minimum water requirements of the population.

Water supply in Bahrain is highly subsidised by the government (75% of costs), moreover the high quantity of wastage of water (Non Revenue Water (NRW) 28.6%, 367.08 m^3/connection/annum) is a major hindrance to tariff reforms.

WATER DEMAND MANAGEMENT PRINCIPLES

Water Demand management options are defined as actions that are deliberately taken by water utilities with the objective of reducing demand for water or matching demand to available supply.

One of the main aims of demand management is to influence consumers to use water more efficiently. This may include the implementation of metering, changed tariff structure, retrofitting, etc. All these activities will directly or indirectly affect consumers.

ROLE OF WDM

The main purpose of WDM programs is to reduce potable water demand to either achieve policy driven water efficiency targets or assist in filling the gap between supply and demand. With such options being significantly lower cost to society than major supply alternatives they are increasingly being implemented by water utilities internationally.

- The role of water conservation/water demand management in ensuring security of supply can be divided into short functions during drought and sustainable long-term.

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- Ecosystems and protection of the environment: reducing water demand reduces water withdrawals impacting on the environment and results in increased stream flow or decreased demand on groundwater source.
- Protect existing water resources.

TOOLS AND MEASURE OF WDM

Water management utilities used worldwide have been reducing potable water usage by implementing life cycle cost-effective water efficiency programs. Demand management options required for a proper use of desalination are mainly divided into three elements: a reduction of unaccounted for water rates, water reuse of wastewater and water pricing. These approaches are recognized as conventional water demand management.

An integrated water demand management plan that incorporate a combination of policy tools that include control regulation, economic incentives for consumer, implementation of water saving technologies and public participation, is seen as the preferred alternative to meet increasing water demand in many countries (Schuringa, 2000).

Demand management measures should be applied as preventive steps to avoid reaching water crisis condition and to maintain sustainability.

Advantages and Disadvantages of WDM

Nielson, 2002 reported the following are the plus and minus of implementing WDM.

Advantages

- Low investment required (except for repair of distribution network, which can be very expensive)
- Income can be generated by water fees
- Incentive to industries and agriculture to improve their efficiency
- Raw water is preserved for alternative uses downstream, including fisheries
- Less sewage treatment capacity required
- To create social awareness on scarce resource among public.

Disadvantages

- Excessive demand management can affect general economic development
- Risk of adverse social impact to the poor part of the population

The negative effects of demand management will be less if measures are introduced gradually, by small steps, and in a transparent and predictable way.

Potential of Water Demand Management (WDM) Options in Implemented Bahrain

In order to satisfy the increase in water demand Bahrain switched over to supply augmentation. This approach alone was found un-reliable to match increase in demand as it was associated with change in water use pattern as well. Therefore Bahrain started implementing WDM in addition to supply augmentation. Below are some of the measures adopted by Bahrain EWA.

Waste Detection and Reduction of Non-Revenue Water in Bahrain

Leak water is not only costly to replace, but also causes problems by undermining roads and buildings by affecting ground stability. As an in extreme condition could cause collapse of infrastructure and building.

In the early 1980s Bahrain's Unaccounted For Water (UFW) which is known as non revenue (NRW) was estimated around 45% of the total production. This high percentage was viewed with concern, a nd EWA began intensifying its efforts to improve the efficiency by implementing Waste Detection Programme.

To begin with, several pilot studies were carried out to check the feasibility of implementation. Three zones in different areas were selected for the study. it was found that by having waste zones understanding and managing the network becomes easy and could thus bring the leakage level down to fairly acceptable figures.

Due to the success of finding leaks in the established zones of the distribution network an ever increasing necessity was felt to zone the maximum area in a very short period. As such from year 1990 to 1995, 365 zones were established which covered 90% of the network.

During the process of establishing waste zones, teams of waste detection inspectors were deployed to carry out waste detection exercises. Statistics showed a gradual steady fall in the percentage of NRW (from leaks) as shown in Table 1.

Radical measures such as replacement of old Asbestos Cement (AC) pipes and low quality service pipes were also initiated to minimise leakages.

Table 1: Established Zones and Fall in NRW (1993–2006)

Year	*No. of Zones Established*	*% Savings on Initial Consumption*	*Demand Reduction (Savings) (m^3/day)*	*Water Saving in a Year (m^3/year)*	*Exercise Cos BD*	*# of Leaks*	*Average Annual NRW %*
85–90	84						
1991	102	17.24	4,209	1,536,285			
1992	73	11.06	3,153	1,150,845			
1993	51	7.24	5,967	2,177,955	48,667	610	3,163
1994	59	12.56	5,427	1,980,855	29,625	358	3,232
1995	24	12.45	2,505	914,325	25,069	114	3,286
1996	14	15.52	3,903	1,424,595	30,750	155	3,571
1997	18	11.07	5,850	2,135,250	44,336	290	2,547
1998	6	9.41	3,079	1,123,835	29,254	225	1,852
1999	1	8.76	3,703	1,351,595	40,666	276	1,796
2000	2	7.50	2,666	973,090	33,906	430	2,288
2001	4	5.95	4,048	1,477,520	42,320	602	2,305
2002	2	7.04	5,649	2,061,885	67,065	954	2,278
2003	1	7.00	4,947	1,805,655	52,330	1,111	2,367
2004	0	6.54	4,440	1,620,600	67,065	1,424	2,588
2005	0	9.45	6,810	2,485,650	75,730	1,211	2,460
2006	0	9.35	6,310	2,303,150	80,800	1,292	2,430

Source: data compiled by author, 2006.

ASSESSMENT OF THE PERFORMANCE OF BAHRAIN WATER DISTRIBUTION NETWORK

Water distribution in Bahrain is supplied by 22 tanks mostly towers. Estimated total length of 1193 km (excluding polythene pipes) form the part of the distribution network. The previously used low density polythene is gradually being replaced by medium density polythene almost 90% has already been replaced.

In the year 2006, the total input into the distribution system was 163 m 398,751 m^3 against the total billed consumption of 116,586,330 m^3, resulting into a gross Non Revenuer Water (NRW) of 28.6% (24.60% after correcting meter under registration).

230 Waste Detection exercises were carried out by the Unit and a total of 837 unseen leaks were located and repaired. Besides, 11 numbers of un-metered/ illegal and abandoned lines were also found and cleared. As a result of the above, 6,310 m^3/day Water was saved. Despite this NRW of 24.6% is considered high and unacceptable.

An attempt to evaluate non revenue water in 2006 has led to correction factors which give a net leakage percentage of 17.6%. Such evaluations based on estimations of the unknown components of water balance, can only achieve a certain level of confidence, since the same methodology which has been applied from 1993 has shown a drop from 31.6% NRW to 24.3% in 2006 as indicated in Table 2.

Table 2: NRW for Period 1993–2006

Year	*% Leakage*	*% NRW*
1993	24.99	31.63
1994	25.25	32.32
1995	25.81	32.86
1996	27.7	35.71
1997	20.9	25.47
1998	16.29	18.52
1999	15.92	17.96
2000	18.3	22.88
2001	18.44	23.05
2002	18.74	22.78
2003	20.08	23.67
2004	18.88	25.88
2005	17.6	24.6
2006	**17.3**	**24.3**

Source: MEW Annual report, 2006

It can be seen from table 2 that during year 1997 to 1999 there was a huge reduction in NRW due to applying different programmes such as replacement of low density Polythene pipes, water ceiling, and increase number of night inspection teams. While during the year 2000 and 2001 NRW increased due to new water production plant was put in service and continuous pumping without no restrictions, But during period 2002–2006 NRW was within 23–25% due to receiving estimated customer water meter billing reading reaching 25%–40% that has an effect in the calculation of NRW.

Suitability of Leak Detection Equipment for Bahrain

The distribution system in The Kingdom of Bahrain comprises more than 3771 km of water mains, ranging in size from 100 mm to 600 mm diameter. In order to curb water wastage due to leaks within the Distribution Network, a leak detection programme is carried out for all Main Lines in the system throughout the year. It involves visual inspection for leaks along all distribution pipeline routes and conducting leak detection tests at night for Distribution Mains of 200 mm diameter and below.

Thus, Soundness Checks for the Entire Network are Carried out at Least Once a Year

Active leak detection is instrumental in finding unreported water leakage and losses within the distribution system.

Leak detection is carried out by Water Distribution Directorate (WDD) has been focused on the analysis of night flow measurements in Waste zones as well as monitoring the waste zone consumption periodically through regular waste meter readings. Also by conducting site surveys using the latest available equipment to study the initial and final night flows, and finding out the percentage of unaccounted for water in each zone contributed to the largest reduction in the quantity supplied.

For invisible leaks—which are very difficult to locate, a step-testing procedure is adopted. This extensive labour-intensive exercise involves dividing of the distribution network into small manageable areas called "Zones". These zones are isolated for carrying out the exercise, and supplied through a single metered feed.

Flow measurements in litres/sec are obtained through pulse units; pressure is monitored through on-line tapping at selected locations within the zones.

This strategy includes regular on-site testing using computer-assisted leak detection equipment, leak mode (correlater), conducting sonic leak-detection surveys, listening sticks, and/or any other acceptable method(s) for detecting leaks along water distribution assets such as Main and Service Lines, Valves, Meters, etc.

Suitability of New Leak Detection Equipment for Bahrain

A pilot study was carried out to evaluate GSM telemetry on site by monitoring the flow and pressure in the district meter area and four waste zone meters in the district, and testing of latest leak detecting system. the suitability of latest leak detection equipment for implementation in Bahrain. District meters area is a new feature of the Bahrain water supply system and have not been tested yet. This pilot test is a good opportunity to make use of the district meter and cover an adequate number of zones.

(a) *Noise Loggers*

The idea behind noise loggers is to record the noise level in early morning hours (2 am to 4 am) in the network to pre-localise possible leaks. Large area can be covered in limited time and removed after survey is over.

For this purpose the noise loggers were deployed in 3 waste zones at different periods. The noise loggers identified some of the leaks; some of the leaks were missed. These loggers work better in areas with DI/AC pipe and are not recommended to be used in area having mainly polythene.

(b) *Tracer Gas Detection*

Tracer gas detection is an ideal solution where noise-based equipment is difficult to use, and pressure-based methods have failed.

At a particular location, localising leak using leak detector failed but by using the tracer gas detection it was easily detected.

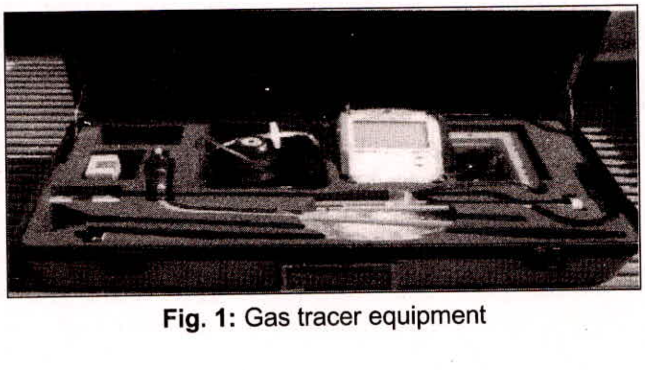

Fig. 1: Gas tracer equipment

The use of gas tracer has proved to be successful especially in locating difficult leaks. The method of injecting the gas through a house connection is efficient and easily applicable. The method has the advantage of being independent from pressure.

Assessment of Leak Causes

During the leak detection exercises the segments of the pipe which showed leakage in step tests were further tested to pinpoint the location of leakages as well as to assess their causes.

From the assessment, it was found that in most of the cases leaks were found on house connections. Therefore eliminating leak causes should start with house connections.

Another common cause of leak is the ferrule, more precisely the ferrule socket. These are of a 2 types: plastic and brass sockets. The plastic sockets have to be handled carefully by the contractor. The polythene pipe must be pressed in and not hammered in. this is often the case and the impact creates a minor crack in the rim of the socket. This crack does not leak immediately but gradually weakens until the leak bursts. This type of socket is not being used anymore for new connections. The brass sockets have shown good resistance. This problem has already been identified by MEW and appropriate action has been taken.

Fig. 2: plastic and brass ferrule sockets where most of leaks occur in house connections

The third leaks encountered are just under the house meters where the line is bent. The cause is obvious as bending the pipe creates stress in the pipe wall.

Application of International Water Association (IWA) Infrastructure Leakage Index (ILI) in Bahrain

The infrastructure leakage index is the best practice method recommended by the IWA. It allows comparison between networks internationally and is widely used as a performance indicator.

For several years, the use of the Infrastructure Leakage Index (ILI) has been actively promoted by various members of the IWA Water Task Force. Considerable debate and discussion has arisen over the use of the ILI as well as the misuse of percentages to define real losses. Such as the recommended range of pressure 30 to 90 m, and the use of ILI methodology in smaller system where the number of connections is less than the recommended minimum number of 3000.

Based on year 2006 figures available by the EWA ILI was calculated as follows:

$$ILI = CARL/UARL \quad \ldots (1)$$

$$UARL = [18 \times L_m + 0.8 \times N_c + 25 \times L_p] \times P \quad \ldots (2)$$

Where, CARL : current annual real losses (L/day)

UARL : unavoidable annual real losses (L/day)

L_m : total length of mains [Ac/DI and polythene] (km)

N_c : number of service connections (connections)

L_p : total length of pipe between property line and customer meter (km)

P : average operating pressure (m)

ILI for Bahrain = 57.5 (75, 207, 395/1, 307, 706)

The value of ILI for the network in Bahrain, as calculated now is very high when compared to international standards. The high ILI value is characteristic of low pressure networks.

Moreover, the calculated value of 57.5 is one of the highest values for ILI on the international level. (Very good to average ILI values range from 1 to 8).

Application of French Linear Leakage Index (LLI)

Another method for performance Indicator (PI) is the French Linear Leakage Index. The French Index is easier to apply especially when not all information to apply IWA method is available or has low confidence limits, which is currently the case of Bahrain.

Linear Leakage Index (LLI) is defined as the rate of losses in the network per network length, and express in $m^3/h/km$

LLI = Loss flow rate during distribution ÷ length of mainlines in $m^3/h/km$

This index is expressed in cubic meter per hour per kilometre. The linear leakage index can be compared to reference values which are proposed by the French water agencies. The French reference values are given in Table 3.

Table 3: Linear Leakage Index Values

Type of Network	*Rural*	*Residential*	*Urban*
Good	< 0.06	< 0.13	< 0.3
Acceptable	< 0.1	< 0.2	<0.4
Mediocre	0.1 < LLI < 0.16	0.2 < LLI < 0.33	0.4 < LLI < 0.63
Bad	> 0.16	> 0.33	> 0.63

Source: G2C environment, 2006 as quoted from French Agence de l'Eau Rhône Mediterranee Corse

The linear leakage index is easy to implement in the first place because it requires less information, especially when measurement data are not accurate, also it is a simple way to compare similar network or different sectors of the same network. It can be used for international comparison as well. The knowledge of LLI is sufficient for local network management and will be at the centre of the network monitoring process to guide field team to sectors to inspect in priority.

With the data gathered from MEW, the overall LLI for year 2006 was calculated to be 0.84 m^3/h/km.

WATER METERING AND TARIFF

Water management is becoming more reliant on accurate customer metering. Most strategies from demand management to detailed water balance depend on reliable metered consumption figures.

Metering is a tool to make people apprise more the value of water and reduce their waste of it as it allows a utility to better locate distribution losses, and charging for water based on use, which is perceived by many as the fairest way to allocate the costs of water supply to users but is an expensive measure, particularly if massive installations are required in a short period (Yepes and Dianderas). This can have an influence home water use, with reductions of up to 25% in areas that previously had no metering; (Grisham and Flemming, 1989).

Review of Metering Policy in Bahrain

The installation of universal water metering for all households including industrial and commercial premises began in 1986, and billing on the basis of metered consumption commenced in 1990, but data from billing system for consumption by customer categories is only available from 1993; the system has been developed by customer services for billing and revenue collection purpose and thus is not ideally suited to analysis consumption.

New service connections are provided only when location for water meter is decided and approved during building permission stage. Thus, supplies to temporary worksites are even metered. As on year 2006, all the 173,000 customer accounts were metered.

Meter Type Installed in Bahrain

Meter size for most of the meters range from 15 mm to 50 mm (About 118,503 meters of 15mm diameter meters are used mainly to meter domestic consumption). However large size meters (150 mm).are used to meter large customers. These residential meters comply with ISC 4046 Class C standard and are positive displacement types, which register reasonably accurate, even at low flow rates. During the course of maintenance or any other investigation, any connection found un-metered or using water by-passing meter is metered without fail.

To ensure that all meters in service are accurate to within 10%, age based periodic replacement of meters is carried out in phased manner together with preventive maintenance.

Meter Reading

EWA has a full fledged directorate (Customer Services Directorate CSD) which is responsible for reading customer meters on monthly basis. Meter readers who are assigned and responsible for different areas are sent to customer premises to take the meter reading.

In the event of meter found stopped or malfunctioning a defect report is immediately raised through complaint centre to replace or repair the defective meter.

Meter Inspection, Repair, and Replacement

Since 1989 MEW has been operating a meter maintenance workshop for maintaining and testing meters to carry out periodical accuracy check of various meters in service.

The policy of EWA is to replace the domestic water meters in service after every six years. Meter workshop raise a request to customer services to submit list of meters installed in the network before six years and more. Most of meters are replaced by defect reports sent by customer services to meter maintenance workshop. These meters are replaced due to stoppage.

Table 4: Meter Maintenance Works Carried Out on Site during the Years 2002–2007

Nature of Work	*Year 2002*	*Year 2003*	*Year 2004*	*Year 2005*	*Year 2006*	*Year 2007*
Customer Meters Leaks/Attended Via Complaint Centre	9,365	14,400	15,589	18,617	14,816	16,858
Customer Meters Defects Atended (Reported by CSD)	21,031	14,323	19,319	23,278	14,350	24,740
Domestic Meters Replaced due to stoppage	11,474	11,362	10,576	14,613	9,150	16,237
Install new customer meters	41	171	1,315	1,523	604	1,101
PPM Bulk Meter (50 mm & over 50 mm)	1,267	2,077	916	1,126	1,195	490
Domestic Meters renewal				721		
Repair (Recycled) Domestic Meters	1,381	1,001	1,840	252*	434	154
Domestic Meters Test	6,959	4,200	2,635	2,628	615	180
Meter Fabrication	2,554	3,646	1,217	3,900	1,860	2
Valve Fittings/Glass wing recycled	198	513	600	120*	440	166
Total Work Done	54,270	51,693	54,007	66,778	43,464	59,762

Source: WDD Annual Report, 2007

There is a policy of annual preventive maintenance of consumers meters. Table 6 indicates water meter maintenance works carried out on site during the years 2002–2005, bulk Meter Repair.

Unfortunately due to shortage of new meters and their spare parts, meters are replaced based on meters found stopped, or defective and not based on age of the meters. As was decided by EWA policy. Table 4 shows the number of meter installed and replaced annually in Bahrain. This table indicated that meters are replaced as meters tend to under-read with age it is likely that a considerable proportion of apparent losses are due to metering error.

Meter Accuracy and Calibration

As accurate metering is essential for assessing authorised consumption, therefore MEW has a programme to measure and calibrate the performance of the various types of domestic water meter. It is ensured that meters are regularly maintained and replaced.

Bahrain water distribution system is operated under low pressure following a strict pressure regime. Bahrain water distribution pressure system is controlled under two pressure regime set. 1. Supply period where an average of 12 m head at tank outlet is provided within the distribution network (04h00 to 06h00 and from 16h00 to 18h00) and restriction period where positive pressure is maintained to satisfy the minimum hydraulic performance of distribution network (06h00 to 16h00 and from 18h00 to 04h00).

Meter accuracy profile is highly affected during minimum flow (Q_{min}) and meter tends to under register by 15% after 5 years in service (Table 5). Besides the revenue losses, leakage level indicated would be misleading. Based on that, water meters in Bahrain are supposed to be replaced after every 6 years in service, as it is not economical to further maintain the meters.

Accuracy studies are continuing to either, further reduce the meter years of service use or use different type of domestic meters to accurately evaluate the NRW percentage.

In addition to the sample calibration of meters from time to time, meters are calibrated on the request of customers complaining of high water bills as well as the request from Water Conservation Directorate based on their investigations of water conservation problems.

Table 5: Meter Accuracy Profile

No of Years Installed	*Average Accuracy (%)*	
	QNOM [1500 l/hr]	*QMIN [20 l/hr]*
Initial	0.05	–0.24
1	–0.58	–1.31
2	–0.98	–1.63
3	–1.68	–6.17
4	–3.27	–9.05
5	–3.71	–13.79
6	–4.60	–15.00
7	–30.00	–77.00
8	–90.00	–100.00
9	–100.00	–100.00

Source: EWA, 2006

Tariff as a Water Demand Management Tool

Establishing an appropriate tariff structure for water supply is one of the most important tasks in a demand management strategy. Low water tariff, discourage water conservation, but if tariff was adequate and provides a price signalling mechanism, consumers will be more careful about the water they are using. Therefore water tariff should be set in such away where all people of all income can afford sufficient quantity of water for their basic needs and lifeline tariff should be within 3–5% of household income as suggested by Kayaga, 2003, Baumann, *et al.*, 1998.

Bahrain—Changes in Tariff, and Effects, Since 1986

Bahrain MEW has adopted increasing block tariff that charge consumers according to the Sectors and the amount of water consumed. In Bahrain, water tariffs are substantially lower than the actual production costs. The government heavily subsidises the domestic and, to a lesser extent, the industrial supply.

The average water production cost in Bahrain is 0.77 $\$/m^3$ and after adding the distribution cost to the domestic sector total çost arrives at 1.05 $\$/m^3$ (MEW, 2005). Water tariff for domestic sector large block (101 m^3 and above) is only charged at 0.56 $\$/m^3$ which is well below the total cost of 1.05 $\$/m^3$ (MEW, 2005). This means that in the case of highest consumption block for domestic supplies, the charges do not cover water production and distribution costs. That means the country is not only subsidizing lower block (1–60 m^3/month) consumers [consumers who are economical in their use of water] but the current tariff also subsidises the large block consumers who are more wasteful in their use of water. Analyzing the above facts it can easily be found that there is a huge gap between the cost of production and tariff. Only 25% of what is actually spent on producing water is received as revenue while the balance (approximately 75%) is borne by the government.

Up to the year 1983 there was a flat rate tariff of BD 0.800. In 1983, this flat rate tariff was modified by the Ministerial Resolution No. 13 (1983), which set the flat rate at BD 1.500.

Table 6: Water Tariff Structure in Bahrain during 1985–1992

Year	*Type of Tariff*	*Consumption/Block*	*Tariff/m³*	*Remarks*
1985	domestic	001–45	45 fils ($0.125)	Applied from 1st April 1985
		46–65	110 fils ($0.308)	
		66 and above	450 fils ($1.26)	
	non domestic	001–450	450fils ($1.26)	Applied from 1st April 1985
		451 and above	770 fils ($2.156)	
1985–1986	domestic	001–50	45 fils ($0.125)	Applied from 1st Sep1985 to 1986
		51–100	110 fils ($0.308)	
		101–150	200 fils ($0.56)	
		151 and above	450 fils ($1.26)	
	non domestic	001–450	450 fils ($1.26)	No change in non domestic tariff since 1985
		451 and above	770 fils ($2.156)	
1986–1992	domestic	001–50	45 fils ($0.125)	Applied from November1986 to April 1992
		51–100	110 fils ($0.308)	
		101 and above	200 fils ($0.56)	
	non domestic	001–450	300 fils ($0.84)	Applied from November1986
		451 and above	400 fils ($1.12)	
1992	domestic	001–60	25 fils ($0.07)	Applied from 1st May 1992
		61–100	80 fils ($0.21)	
		101 and above	200 fils ($0.56)	
	non domestic	001–450	300 fils ($0.84)	No change in non domestic tariff since 1986
		451 and above	400 fils ($1.12)	

Source: Electricity and Water Authority, Bahrain, 2006

First incremental water tariff was imposed in Bahrain in 1985 by the Ministerial Resolution No. 3 (1985). This tariff structure was modified and strengthened by the Ministerial Resolution No. 14 (1985) and later by the Ministerial Resolution No. 19 (1986).

In 1992 tariff structure was again revised under Ministerial Resolution No. 2 (1992) and is currently in force. Relevant details regarding each tariff structure are listed in the Table 5.

In Bahrain, water production cost is low (US$ 0.065/m^3), groundwater is blended with desalinated water using a ratio of about 1:3, respectively, for drinking use. More importantly, the gap between production costs (including production, transmission, and distribution) and revenues is quite large, resulting in large subsidies portion ESCWA, 2005.

Although Bahrain has employed increasing block tariff system since 1990, but per capita consumption is high due to the rate itself is very low.

WATER CONSERVATION

The term Water Conservation is implemented to ensure the minimization of loss or waste of water, the preservation care and protection of water resources and the efficient and effective use of water. It should be both an objective in water resource management and water services management as well as strategy.

Water conservation is a complex interconnecting system with a variety of aspects—from consumer education to advanced technological equipment (Atallah, *et al.*, 2004).

Numbers of water saving strategies for water efficiency have been developed worldwide. Some examples include: landscape water use audits, water efficient landscaping, home and industrial retrofits, water reclamination, and public education programs.

Water conservation must be seen as a basic component of integrated water resources management, and public awareness and education are basic tools needed to be guaranteed the participation and involvement of the public in water conservation (WMO, 1992; UN 1993a, b).

Over the years Water Conservation has formed its growth to such an extend to become an individual directorate.

Water Conservation Technical Activities

The water conservation program in Bahrain is based on identifying and serving the consumers who are in need of conservation. The target group is identified with the help of a computer program, which has been developed to identify customer who record abrupt or abnormal increase in consumption. Conservation Inspectors and Technician investigate valid selected cases. Many of these cases are investigated even before the customer gets the water bill and notices the increase in consumption. The increase in consumption may happen due to leakage, excessive garden watering, or misuse. About 30% of high consumption was due to leaks and almost 80% of it occurred between the meter and the tank. Most of the leaks were detected in buried polythene pipes, which are used commonly in this section. Leaks occur due to the following reasons:

- high pressure from tower supply
- Inferior quality of the polythene pipe
- Bad plumbing practices
- Improper bedding/filling for pipes
- Aging of the pipes.

Reducing Water Connection Size in Government and Public Places

Water misuse in the government and public places is common, especially in garden watering. To reduce misuse, the right water connection size should be given to the location, Table 7, shows the average of 25% reduction in consumption in six premises after decreasing their water connection to the actual required size (Abdulla, 2003).

USE OF SAVING DEVICES

Electronic Taps

A number of locations were proposed to install Electronic Taps (ET) for the pilot test. These locations were initially selected based on their high water consumption and large number of users.

Selection of places where ETs were installed was Apart from Bahrain Mall, Al Abraj Restaurant—Sehla and Seef Mall.

Daily water meter readings were recorded for each study location and the daily consumption was obtained by subtracting consecutive readings from each other. Determination of daily consumptions was necessary to monitor the variation in consumption and to establish the magnitude of abnormalities during special events or due to leaks and misuse. Average Daily Water Consumption was determined after correcting daily consumptions for any abnormalities.

Table 7: Saving in Reducing Connection Sizes in Government Places

Type of Premises	*Old Meter Size*	*New Meter Size*	*Consumption Before Meter Exchange (m^3/day)*	*Consumption after Meter Exchange (m^3/day)*	*Saving*
School 1	2"	1"	17.4	38	–20.6
School 2	2"	1"	10.3	10	0.3
School 3	2" & 1"	1"	15.2	9.8	5.4
School 4	2" & 2"	1"	43.5	25.6	17.9
Police Station	2"	1"	63.6	16	47.6
Driving school	2"	1"	7	18.3	–11.3
Total			157	117.7	39.3
Average			26.17	19.62	6.55
Average % saving					25.03

Source: Abdulla, 2003

Table 8: Percentage Water Saving achieved by Installing Electronic Taps

Location	*Reference Average Daily Water Consumption (m^3/day)*	*Average Daily Water Consumption (m^3/day)*	*% Water Saving*	*Water Saving (m^3/day)*	*Annual Water Saving (m^3/year)*	*Annual Saving (BD)*	*Pay Back Period*
Al Seef Mall	2.753	2.171	21.1	0.582	212.4	85	1.3
	2.753	1.294	53.0	1.459	532.5	213	
Bahrain Mall	14.85	9.709	34.6	5.141	1876.5	751	six month
Al Abraj Restaurant	1.117	0.709	36.5	0.408	148.9	60	
	1.117	0.65	41.8	0.467	170.5	68	3.2

Percent Water Saving resulting from the use of ETs at each study location was determined by comparing the Average Daily Water Consumption after installation with the Reference Average Daily Consumption determined over a minimum period of two weeks before installation. As detailed in Table 8.

EDUCATIONAL AND PUBLIC AWARENESS

Education and awareness are key components of any successful WDM policy and before the consumers can be educated, it is necessary to ensure that the personnel working for water supplier are fully aware of the need to manage water demand. Therefore it is essential that training sessions be provided to introduce and explain in details the various concepts of WDM throughout the water supplier's organization.

Many public awareness and education programs are running in Bahrain. The objective of such programs is to raise the awareness level among the water consumers. Most of the programs are not well planned and failing in conveying their message to the target groups. Furthermore, the awareness campaigns are crisis driving which conduct on a seasonal basis.

Education in Schools

School education is one of the most important aspects of the education and public awareness component of any WDM strategy. If the children can be convinced of the benefit to the community and environment, of WDM measures, they will convey the message to their parents.

School education in Bahrain is only targeting primary and intermediate students, it takes form of lectures given to students, also the water Conservation Directorate and Ministry of Education work together to create an education campaign that forms part of the Education syllabus in school.

Education at Home

Education at home can be achieved through a variety of measures. The materials required will vary from one area to another and from one country to another, depending on the level of service and the availability of the specific media to the consumer. One of the successful approaches to educating the consumers at home is through the children and the school education system.

Findings and Conclusions

Waste Detection

From the assessment, it was found that in most of the cases leaks were found on house connections; another common cause of leak is the ferrule, more precisely the ferrule socket and the third leaks encountered are just under the house meters where the line is bent.

The value of ILI for the network in Bahrain, as calculated now is very high when compared to international standards. The high ILI value is characteristic of low pressure networks.

In Bahrain majority of domestic meters installed are volumetric mechanical (piston type) meter. These meters are better than single jet as it is accurate at low flow and on other hand volumetric meters tend to under register after a certain period of time.

Meter are supposed to be replaced after 6 years, unfortunately this policy is not practiced in Bahrain these days due to shortage of meters and meter spare parts as well a meter bench test to carry out meter accuracy test.

In order to measure the low flow at low flow rate it is advice to test installation of Low Flow Control Valve (LFC). In Bahrain the pilot test is undergoing and results are encouraging.

The current tariff is low Water tariff in Bahrain needs to be reformed and at the same time consumers given more incentives to encourage water conservation.

There are three objectives for water tariff:

1. *Efficiency:* gives signal future costs.
2. *Cost recovery:* revenue should pay for operation and maintenance and debt service.
3. *Equitable:* make tariff affordable.

Electronic Taps (ET) can be used to save water. The extent of water saving will depend on the flow rate through the taps because the taps will either fully open or close. Flow through the taps can be controlled using flow restrictors such as aerators or control valves. Using ETs was found to reduce consumption by 42 to 53%. At the price of 85 BD per unit, the use of ETs is economically feasible (pay back in less than two years).

RECOMMENDATIONS

Arrives the maths of production cost, O&M cost, capital cost and publish the figure with the subsidy. Gradually at the public are aware about the cost and price sense, the subsidy can be curtailed.

Tariff and recovery rates continue to remain critical issues in all developing countries. There is general political resistance to tariff increase and in maintaining tariff levels in real terms to meet production cost.

Tariff structure should be sufficient to cover O&M costs, and development plans while at the same time providing low lifeline rate for low consumption and penalty rate for higher consumption.

Government subsidised water price that leads to inefficient allocation of water between consumption sectors. Redesigning the water tariff system is necessary to achieve the efficiency.

It is recommended to replace meter based on age, cumulative volume against replacement cost, rather than age alone.

It is recommended the use of Electronic taps at places where average daily water consumption per tap is in excess of 0.5 m^3. These places can be travel terminals, shopping malls, restaurants, mosques and the like. Stickers containing visual aids to explain the operation of the ETs may be needed at places where people from rural areas who are not familiar with such facilities are expected.

Adopting water metering and reducing the amount of NRW through leak detection, repair and elimination of illegal connection will help in increasing water use efficiency in Bahrain.

When implementing WDM programs, public education and awareness should be considered as the key to address the conservation of water uses and wining support for the new policies. Most of public awareness programs in Bahrain are seasonal marginal.

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