Practical Paper

Freshwater consumption in Kuwait: analysis and forecasting

Jasem M. Alhumoud

ABSTRACT

With the rapid growth of population coupled with increasing urbanization and agriculture, the demand for water in Kuwait is continually on the increase. The main water source in the State of Kuwait is from desalination with small quantities from underground aquifers. The objective of this research is to analyse and forcast water consumption in Kuwait. Therefore, consumption and other related data were collected randomly from different households within Kuwait. Total water consumption in Kuwait has increased from 255×10^6 imperial gallons ($1.159 \times 10^6\,m^3$) in 1954 to 102×10^9 imperial gallons ($463.7 \times 10^6\,m^3$) in 2003, which represents a 400-fold increase. The government of Kuwait heavily subsidizes water production. While 1,000 imperial gallons ($4.546\,m^3$) of water costs the Ministry of Energy (MOE) KD3.21 (US$11.00) to produce, the customer is charged KD0.8 (US$2.72) for it. Predictions of future water consumption would help the government in its efforts to reform its subsidy policy. Results of the analyses indicated that there is considerable waste of fresh water by the average Kuwaiti household. The paper concludes with useful remarks to both the Minsitry of Energy (MOE) and the citizens of Kuwait on water usage rationalization.

Key words | forecasting, fresh water, households, Kuwait, water consumption

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INTRODUCTION

The problem of securing and gaining reliable water supplies has been an issue of great importance to the people of Kuwait ever since the earliest days of settlement in the region. Today, as the population and industrial developments grow, the water issue promises to become more acute.

Signs of water scarcity worldwide are numerous. Water tables are falling, lakes are shrinking, rivers are getting more polluted and wetlands are disappearing. Engineering solutions to water shortages include schemes such as building river diversions (e.g. in California), construction of dams and other expensive projects, some with questionable environmental consequences (Al-Rashed *et al.* 1998; Alhumoud 2002).

doi: 10.2166/aqua.2008.036

Supply of water to urban areas requires major capital investment in storage, treatment and recirculation facilities. The demand for water increases with population growth and with industrial and commercial development. Furthermore, the per capita consumption of water has generally tended to increase rather than decrease, although this can be expected to be largely a function of lifestyle and population density. Since 1950, global water demand has more than tripled to an estimated annual level of 4,340 km^3 in 1993. Because of improved standards of living, the per capita water use worldwide has increased dramatically to 193,600.00 gallons (880 m^3) per year. This amount is 50% more than it was in 1950 and continues to grow. To meet this rising demand, responsible policy-makers have mainly emphasized the construction of ‘water development’ projects, particularly dams and river diversions. Today, more than 36,000 large dams have been built around the world to control floods, provide energy, irrigation, industrial supplies and drinking water to a growing global population (Alhumoud & Al-Ghusain 2003).

Kuwait is situated in an extremely arid region that receives only about 100 mm (3.937 in) of rain annually. The average annual rainfall ranges from 40 to 240 mm and the total annual evaporation rate ranges from 2,500 mm in the coastal areas to more than 4,500 mm inland. The amount of renewable aquifer volume is very limited and shallow alluvial aquifers provide some renewable groundwater only in those limited coastal strips. Large, deep aquifers are present in the region, which contain nonrenewable supplies of fossil water, but these have a finite life and quality limitations. However, even these are rapidly depleting. In the past the people of Kuwait relied on a scant number of wells to satisfy their water needs. Those wells accompanied by fresh water transported by boats from Basra, Iraq, were the main source of water supply to the people. Transporting water by boats continued for some time. In 1939, a company was established to manage the fleet of water carriers from Iraq, and three storage reservoirs were constructed on the shore. The first major breakthrough came in 1951 when the Kuwait Oil Company (KOC) built a small sea water desalination plant with a capacity of 80,000 imperial gallons (364 m^3) per day at the port of Al-Ahmadi (Mina Al-Ahmadi), and distributed part of the water to towns in Kuwait. The first major desalination plant was built in 1953 with a capacity of 1 million imperial gallons per day (4,546 m^3/day). In 1978, another desalination plant was built in Doha. The capacity of the Doha plant is 42 million imperial gallons per day (190,932 m^3/day) (Al-Ruwaih *et al.* 2000; MOE 2004; MOP (Ministry of Planning) 2004).

The country was and is still very anxious to exploit all available groundwater: both fresh water for drinking and brackish water for irrigation. As for fresh groundwater, it is considered a matter of prime importance. Fresh groundwater was discovered in limited quantities in the north of the country at the Al-Rawdhatain and Umm Al-Aish fields. Pumping operations commenced in 1962; the estimated natural reserve of both fields is about 40 billion imperial gallons (182×10^6 m^3). In 1980, the Rawdhatain Water Production and Bottling Projects started to produce 396,039.6 imperial gallons per year (1,800 m^3/year) of mineral water. The Umm Al-Aish field is currently producing 1,760,176 imperial gallons per year (8,002 m^3/year) (Omar *et al.* 1996; Mukhopadhyaya *et al.* 2000).

In addition to fresh water, the country makes use of its large supply of brackish groundwater. The Ministry of Energy (MOE) in Kuwait distributes water to consumers through a separate network parallel to the freshwater network. The brackish water is supplied to consumers free of charge at a rate of one day per week and only from 7 a.m. to 5 p.m. It is intended to be used for various purposes, such as blending with distilled water, irrigation, livestock watering and construction works. Therefore, the analysis done in this paper is for fresh water only.

Over the past three decades, the country has witnessed an unprecedented economic and social transformation. A significant portion of oil revenues has been used to modernize infrastructure and improve the living standards of the population. Water supply and sanitation services have been made accessible to a large percentage of the population. Life expectancy increased by about 10 years to 74 years during 1980–2000 and literacy rates increased from 20% to about 90% over the same period. Gross national income per capita (GNI) was estimated at about US$19,480 in 2003 with gross domestic product (GDP) at about US$16,240 and an average population growth rate of 3.5% (MOP (Ministry of Planning) 2004; World Bank 2005).

During this period, total water demand has increased dramatically as a result of high population growth, improvements in the standard of living, industrial development in major urban centres and efforts to increase food self-sufficiency. The total water use for all sectors increased about five and a half times from 186 million m^3 to 993 million m^3 while the population nearly doubled from around 1.4 million to 2.54 million during 1980–2003.

As can be observed in Figure 1, the average consumption and, therefore, production of water has increased gradually with the exception of the years 1990 and 1991. In addition, Figures 2 and 3 show the per capita consumption in Kuwait and in various other countries, respectively. The ratio of water distribution and water proportion as distributed among the three sectors, namely domestic,

 Journal of Water Supply: Research and Technology—AQUA | 57.4 | 2008

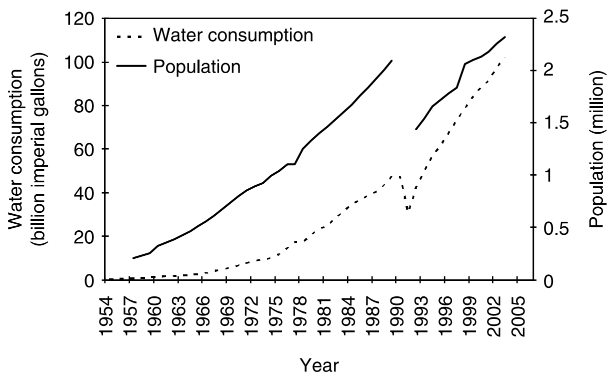

Figure 1 | Trends in freshwater consumption and population in Kuwait (1954–2003).

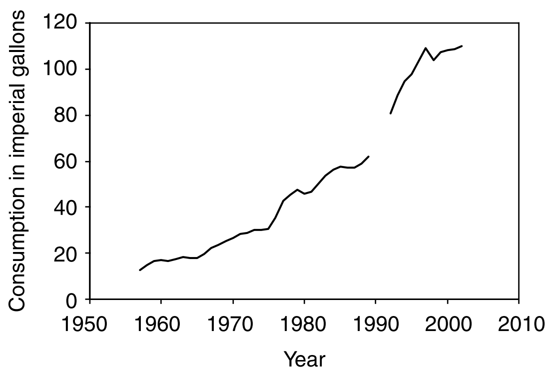

Figure 2 | Daily per capita consumption of fresh water in Kuwait (1957–2003).

industrial and agricultural waters in Kuwait, is illustrated in Figure 4. The domestic sector covers both the industrial and commercial demands while the agriculture sector accounts for water used in irrigation of agricultural lands and landscaping (Alhajri 2005). The per capita water consumption is increasing yearly as well, with a slight drop during 1998. However, while there was a small

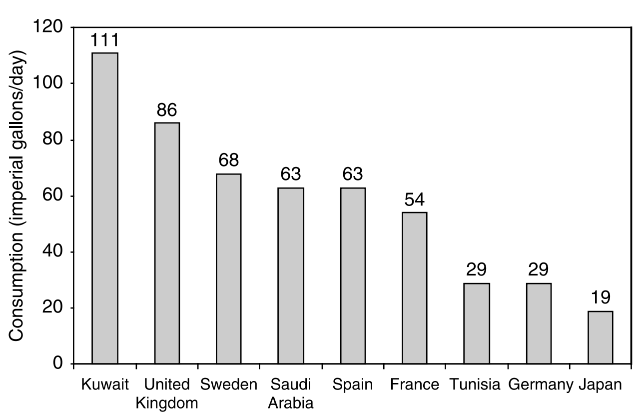

Figure 3 | Daily per capita fresh water consumption in different countries.

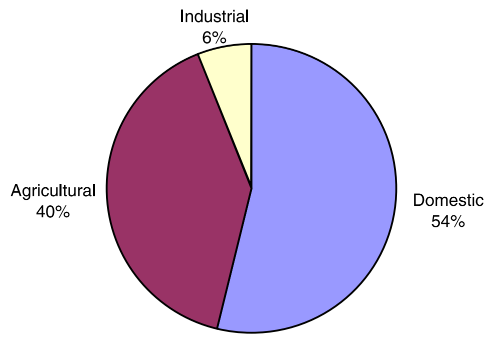

Figure 4 | Distribution of water uses by sector in Kuwait.

decrease in the per capita water consumption rate in Kuwait during 2003, the current rate is still significantly higher than that reported for Western Europe, Japan and Middle Eastern Countries (KEPS 2004; Alhajri 2005). One should note that this decrease was due to the invasion of Iraq and the start of the Gulf War. Two factors explain the current alarming increase in urban water demand. The first is the rapid population growth and the second is the rise in per capita consumption. Average population growth in Kuwait over the last two decades is indeed among the highest in the world (around 3.5% per annum). More strikingly, the average daily water consumption per capita was only around 27 imperial gallons (123 litres) in the 1960s and has now increased to around 110 imperial gallons (500 litres). Nowhere else in the world has per capita water consumption risen so rapidly over a similar time period. Moreover, it is worth mentioning that, by the end of 2003, the total length of the entire water network was 7,376 km, while the number of consumers connected to the freshwater network totalled 122,111 and consumers connected to the brackish water network totalled 70,969 by the end of the same year (MOP (Ministry of Planning) 2004).

Water tariffs are generally quite low, representing on average no more than 10% of cost, which implies that no incentives exist under current policies for consumers to save water. While 1,000 imperial gallons (4.546 m^3) of water costs the Ministry of Energy (MOE) KD3.21 (US$11.00) to produce, the customer is charged KD0.8 (US$2.72) for it. Furthermore, water metering and billing are only loosely applied to nationals. Some Kuwaitis have not been paying their water bills for over 15 years and no action has been taken by the ministry yet. Moreover, to make matters worse, recently the ministry has accredited KD2,000.00

(US$6,800.00) to every Kuwaiti household on their water bill. Current government policies of heavily subsidizing the water sector could become counterproductive in the future. Heavy reliance on subsidies will not only exacerbate rapidly rising water demand, but will also place an intolerable burden on national budgets. A substantial amount of water will have to be supplied by costly desalination plants. Even though newer and more cost efficient desalination technologies have become available, water subsidies alone could take away up to 10% of oil revenues by 2025 (Busheri & Burney 2003; World Bank 2004).

RESEARCH METHOD

Utilizing the experience gained by the research team during the first survey in 2000–2001 (Alhumoud 2002; Alhumoud & Al-Ghusain 2003), a structured, yet simple questionnaire was developed and pre-tested to obtain information on households' socio-economic traits, and residence characteristics as well as the daily water-consuming activities of sample households. The computation of the sample size, the development of a questionnaire, the determination of sampling technique and sample population were all addressed in the survey design. The computation of the sample size was made in accordance with the commonly utilized statistical equation (Walpole & Myers 1985). A confidence level of 95%, and an error level of ±5% were considered to be appropriate by the research team. By utilizing a recommended value of 0.5 for the standard deviation (for maximum possible standard error of the mean), the minimum required sample size may be computed from the following equation:

$$\sqrt{N} = [(Z_{1-\alpha/2}{}^{*}S)/e] \quad (1)$$

where: N is the minimum required sample size; Z is the number of units of the standard deviation in a standard normal distribution curve ($Z = 1.96\%$, $\alpha = 5\%$); α is the significance level; S is the standard deviation (0.5 when the true population standard deviation is not known); and e is the acceptable error (± 5%). Equation (1) and the above input values result in a minimum sample size of 385.

The questionnaire was coded and distributed in a systematic and random fashion among households in the six governorates of the State. Out of nearly 2,500 distributed questionnaires 2,025 completed responses (81%), from 64 districts were processed for the analysis. SAS software (SAS/ETS 1991) was utilized for processing and analysing the data. The objective of the study was to examine the water supply and consumption situation in Kuwait.

RESULTS

Households' socio-economic and water consumption profiles

An average sample household had a family size of 6.5 persons and a monthly income of KD1,017.00 (US$3,356.00). The socio-economic profile of the sample households, addressed in the questionnaire, included the family size, income, residence type, number of servants and number of employed drivers. As presented in Table 1, less than 2% of the samples were single households, and nearly 30% had a moderate family size of 4 or less. The largest percentage (48.8%), however, had a family size of between 5 and 7 persons.

Less than 30% of the sample respondents had a monthly income of KD500.00 (US$1,700.00) or less. The largest percentage made between KD1,001.00 and 1,500.00 per month (US$3,403.40–5100.00). Only 4.2% made more than KD2,000.0/month (US$6,600.00/month). Approximately 65% of the sample respondents lived in villas, and while nearly half of the sample households employed a maid, more than 37% had two or more. All of the 2025 households in the survey had at least one car, 57% had at least five cars, 15% had three cars, 8% had two and only 2% had one car per household. Less than a quarter of the sample households employed a personal driver (Table 1). The maid and the employed drivers, although provided with their own quarters, reside with the family within the same dwelling unit, and thus they are thought of as family members.

The average monthly water bill varies from house to house, 39% had a bill between KD30.60 and 49.12/month (US$104.00–167.00/month), 30% had greater than KD68.8/month (US$234.00/month), 17% between KD48.90 and 69.00/month (US$171.00–234.00/month), and 14% had a bill between KD19.70 and 29.70/month (US$67.00–101.00/month).

Table 1 | Distribution of sample households' socio-economic characteristics

Variable Name	Distribution Frequency	Percentage	Cumulative percentage
Family size			
1	32	1.6	1.6
2	95	4.7	6.3
3	156	7.7	14.0
4	316	15.6	29.5
5–7	988	48.8	78.3
8–12	389	19.2	97.6
>12	49	2.4	100.0
Monthly income (KD)*			
≤ 500	555	27.4	27.4
501–1,000	494	24.4	51.8
1,001–1,500	666	32.9	84.6
1,501–2,000	227	11.2	95.8
2,001–3,000	49	2.4	98.2
> 3,000	36	1.8	100.0
Residence type			
Villa	1,324	65.4	65.4
Apartment	701	34.6	100.0
No. of servants			
0	304	15.0	15.0
1	962	47.5	62.5
≥2	761	37.6	100.0
No. of employed drivers			
0	1,571	77.6	77.6
1	454	22.4	100.0
Number of cars			
1	43	2.1	2.1
2	158	7.8	9.9
3	304	15.0	24.9
4	370	18.3	43.2
≥5	1,150	56.8	100

*KD = US$3.4 (2003 rate).

Water use

Since people in Kuwait use both fresh and brackish water for their daily needs, the respondents were each asked to give an idea of what kind of water they used in their different daily activities.

Half of the households use bottled water, while 40% use tap water and 10% use both for drinking (Table 2). It was also found that 44% of the people water their garden with fresh water, 29% with brackish water and 14% use both types of water for gardening. By the same token, it was found that 43% of the households with a garden water it at least three times per week, 12% twice, and 2% once a week (Table 3).

An interesting element in the survey was a question regarding the number of times laundry is performed each week. It was found that 44% of the respondents do their washing seven days a week, 23% twice, 13% four times, 12% three times, 5% once, 2% five times and 1% six times a week (Table 4). Washing the entire house (floor scrubbing) consumes a lot of water; 46% of the people wash their houses once a week, 31% twice, 13% three times, 4% four times, and 6% at least five times per week (Table 5).

Table 2 | Type of drinking water preferred

Type of water	Percentage (%)
Bottled water	50
Tap water	40
Bottled water & tap water	10
Total	100

Table 3 | Number of times garden is watered each week

Number of times per week	Percentage (%)
1	2
2	12
3	43
4	32
5	10
6–7	1
Total	100

Table 4 | Number of times clothes are washed per week

Number of washes per week	Percentage (%)
1	5
2	23
3	12
4	13
5	2
6–7	45
Total	100

Table 5 | Number of times floors are scrubbed each week

Number of washes per week	Percentage (%)
1	46
2	31
3	13
4	4
5–7	6
Total	100

The use of a shower or bath is another cause of high water consumption. Our results show that every member of the household takes a shower or bath at least once a day or once every other day. Finally, an attempt has been made to find out what bothers people most about the water; is it colour, taste, impurity or any combination of these? Colour and impurities in the water are usually caused by the corrosion of the old pipes (ductile iron) in the network. Subsequently, since the operating temperatures are high in Kuwait, increased chlorine dosages are used to achieve effective disinfection. However, this causes taste and odour problems related to excessive chlorine residuals. Therefore, it was found that the colour of the water is the most annoying item for the respondents. Fifty-four per cent of the people are bothered by colour alone, 28% are disturbed by the taste of water, and 23% are disturbed by the impurity of the water. Notice that the total exceeds 100% (105%), which means that some people are bothered by more than one item at the same time. These findings all point to the peculiarities of the Kuwaiti households: large family sizes, big houses, high auto ownership rate, and multiple servants and drivers – all important contributors to the daily consumption of water.

Socio-economic and water consumption interrelationships

Correlation analysis is usually employed to examine the degree of association between two variables. The result of the data analysis of correlations indicated that a number of households' socio-economic traits and their water consumption were positively and significantly (at the 95% significance level) correlated. Factors such as household size, income and social habits (number of cars, type of residence) all affect the daily water consumption rate of the household. Therefore, a correlation analysis was performed on the data to quantify the magnitude of these associations. For example, the quantity of water consumption was positively correlated with the size of the house in square meters ($\gamma_{xy} = 0.355$); with the type of residence (villa or apartment) ($\gamma_{xy} = 0.325$); with the number of showers/baths taken per week ($\gamma_{xy} = 0.312$); with the size of the family (number of occupants in a household) ($\gamma_{xy} = 0.307$); weekly laundry ($\gamma_{xy} = 0.304$); with the households' monthly income ($\gamma_{xy} = 0.257$); and with the number of cars in the household ($\gamma_{xy} = 0.224$). These correlation coefficients all conform to expectations.

As presented in Table 6, all of the sample households' socio-economic factors were positively and significantly associated with the quantity of water they consume. The variable most strongly correlated with the quantity of daily water consumption was the size of the house (HS). A significant difference in the rate of daily water consumption is observed for villas with an area of less than 500 m^2, more than 500 m^2 but less than 750 m^2, and villas larger than 750 m^2 ($r_{xy} = 0.355$, $p < 0.0001$). To test this hypothesis, a summary analysis was performed on the data with the aim of determining the daily water consumption for households of equal sizes but with different residential types. However, for apartment sizes an average of 150 square metres was considered, since the vast majority of the apartments in Kuwait are about this size.

In general, a major factor contributing to the consumption of household water is the size of the household (number of residents in a household). The larger the family size, the greater the quantity of water consumed. However, in addition to the size of the family, a number of other household socio-

Table 6 | Matrix of correlation coefficients

	AWB	RT	HS	NOO	NOC	CWPW	PSPW	HMI
AWB	1.00	0.325	0.355	0.307	0.224	0.304	0.312	0.257
RT		1.00	0.245	0.324	0.186	0.068	0.018	0.192
HS			1.00	0.232	0.178	0.162	0.184	0.302
NOO				1.00	0.461	0.311	0.170	0.176
NOC					1.00	0.106	0.039	0.321
CWPW						1.00	0.114	0.232
PSPW							1.00	0.131
HMI								1.00

AWB, average water bill; RT, residence type (villa or apartment); HS, house size (m^2); NOO, number of occupants in the household; NOC, number of cars in the household; CWPW, clothes washing per week; PSPW, people showering/bathing per week; HMI, household monthly income.

economic variables may also significantly affect the daily water consumption rate of households residing in single-unit villas. The frequency of clothes washing constitutes one such variable, which contributes to higher levels of water consumption by the residents of single-unit villas.

This was followed by residence type (villa or apartment) ($r_{xy} = 0.325$, $p < 0.0001$); quite clearly, and as was hypothesized, individuals residing in villas consume considerably higher quantities of water each day when compared with their counterparts of equal size households living in apartments. This was followed by number of weekly showers/-baths taken ($r_{xy} = 0.312$, $p < 0.0001$), the number of people residing in the household ($r_{xy} = 0.307$, $p < 0.0001$), the number of weekly clothes washes ($r_{xy} = 0.304$, $p < 0.0001$), the household monthly income ($r_{xy} = 0.257$, $p < 0.0001$) and the mean number of cars owned by the household ($r_{xy} = 0.224$, $p < 0.0007$). All of these findings conform to expectations.

Forecasting water consumption (demand)

Forecasting water demand in Kuwait carries major policy implications for both the Kuwaiti government and the water industry. The Kuwait government heavily subsidizes water consumption, which constitutes a heavy burden for the government. Predictions of future water consumption (demand) would help the government in its efforts to reform its subsidy policy and find alternative methods for reducing its spending. Also, the water sector invests continuously in expanding its production capacity. It would be very useful indeed to form an idea about the future demand for this public utility. The research uses time series methodology in forecasting water consumption. This methodology has not been used before in forecasting consumption and/or demand for public utilities in Kuwait.

In time series, the series is first examined for stationary. This can be done by computing the autocorrelation function (ACF) and the partial autocorrelation function (PACF) for the original series (Granger & Newbold 1986; Newbold & Bos 1994) or by formal unit root analysis (Dickey *et al.* 1986). The correlograms associated with ACF and PACF are often good visual diagnostic tools (Hanke & Reitsch 1995). The tentative model is then estimated. A number of alternative parameter estimation procedures are commonly used. These various procedures typically yield quite similar estimates when the sample size is large. However, for shorter series, there can be larger differences, particularly if the model involves substantial moving average terms. The full-maximum likelihood approach is usually preferred in those cases for which different estimation procedures yield significantly different results (Newbold & Bos 1994). The residuals from the tentative model are examined to determine whether or not they are white noise. The adequacy of the model is also indicated by the Box-Ljung statistic (Box & Jenkins 1976; Ljung & Box 1978). Model inadequacy is indicated by large absolute values for the residual autocorrelations, and consequently large values for the Box-Jenkins statistic. If the residuals are white noise, the tentative model is probably a good approximation of the underlying stochastic process. If they are not, then the process is started all over again. Therefore, the Box-Jenkins modelling involves identifying an appropriate autoregressive integrated moving average (ARIMA) process, fitting it to the data, and then using the fitted model for forecasting. One of the attractive features of the Box-Jenkins approach to forecasting is that ARIMA processes are a very rich class of possible models and it is usually possible to find a process which provides an adequate description to the data (Box & Jenkins 1976).

The model finally selected can then be used for forecasting. Forecasts can be made for a single period or for several periods in the future. Confidence intervals can also be constructed about these estimates. In general, the further into the future the forecast is, the larger the confidence intervals will be. Therefore, as more data become available, the same model can be used to revise the forecasts by

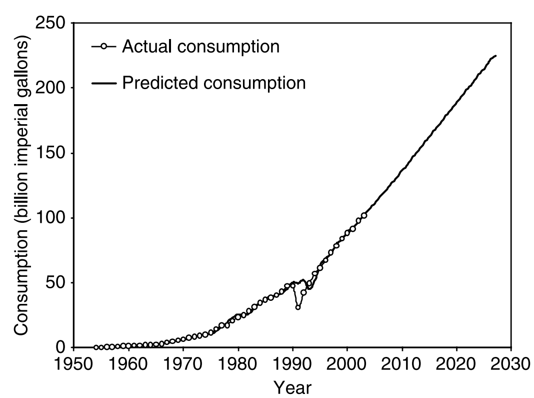

Figure 5 | Actual and predicted fresh water consumption in Kuwait (2003–2025).

Table 7 | Statistical analysis results

Parameter	Estimate	Std error	t-value	Approx. Pr > |t|	Lag				
MU*	2.51612	110.89	0.02	0.9819	0				
MA1†	0.40322	0.1944	0.01	0.9945	12				
Constant estimate	2.51612								
Variance estimate	1095.418								
Std error estimate	1046.622								
AIC‡	729.9897								
SBC§	737.0345								
Number of residuals	43								
To lag	Chi-square	DF	Pr > Chi-sq	Autocorrelations					
6	25.31	3	0.0001	0.126	−0.216	−0.140	0.104	0.478	0.377
12	39.19	9	0.0001	−0.065	−0.104	−0.222	0.295	0.206	−0.168
18	41.93	15	0.0002	−0.049	−0.122	0.076	0.005	0.089	0.080
24	53.65	21	0.0001	−0.230	−0.065	0.025	0.167	−0.166	−0.131

*Parameter estimate.
†Moving average process.
‡Akaike's information criterion.
§Schwartz's Bayesian criterion.

choosing a different time origin (Box & Jenkins 1976; Hoff 1983; Chatfield 1989; Anderson 1994; Hamilton 1994; Anderson & Finn 1996; Fuller 1996; Anderson 2003).

In our case, a series of 50 observations representing total annual residential water consumption in Kuwait during the period from 1954 to 2003 were collected. Figure 1 gives a plot of the original series. A close inspection of the figure suggests that water consumption in Kuwait experienced exponential growth over the sample period with the exception of the period 1990–1992. The reason for this was explained above. The series suggests a constant proportional growth rate of approximately 8% per annum. This was estimated using the regression:

$$\ln C_t = b_0 + b_1 T + u_t \tag{2}$$

Where, C_t is the total annual water consumption in period t, T is time, b_0 and b_1 are constants and u_t is the error term. The coefficient b_1 represents the (constant) proportional rate of growth (r), given by:

$$r = (\mathrm{d}C/\mathrm{d}T)/C \tag{3}$$

The final model was estimated using the SAS program (SAS/ETS Software 1991) and it can be written as follows:

$$Y_t + 96.6 = 0.11(Y_{t-1} + 96.6) + e_t \tag{4}$$

Where, Y_t is the series of water consumption and e_t is the error term. As shown in Figure 5 and Table 7, the above model appears to provide a good fit for the water consumption. None of the Q statistics values is significant and none of the residual autocorrelations is very large in the autocorrelation check of residuals, indicating that the model provides a good fit to the data. The seasonal moving average parameter estimate of 0.11 is significant. In addition, the Akaike's information criterion (AIC) (Akaike 1974; Harvey 1981) and Schwartz's Bayesian criterion (SBC) (Schwartz 1978), which measure the goodness of fit, are small, indicating good fit of the model. Moreover, more elaborate models did not produce superior results. Therefore, this model adequately describes the behaviour of the water consumption time series. Figure 5 shows how close the forecasted values (2004–2025) given by the model are to the actual values, and the results suggest a very good fit.

CONCLUSIONS AND RECOMMENDATIONS

The development of the State of Kuwait or any other nation inevitably involves increased consumption of water.

Since water consumption and the deterioration in the quality of available natural waters will certainly continue, it is imperative that the replenishment and qualitative improvement of natural waters proceeds faster than their consumption and deterioration, to allow society to develop normally. There is an evidence of lavish consumption of water by the people of Kuwait: for example, in washing their cars, cleaning houses (floor scrubbing) and washing their clothes. We estimated that the amount of water used in washing a car varies from 7 gallons (0.032 m^3 (32 Litres)) for those who use buckets to fetch water to 50 gallons (0.227 m^3 (227 Litres)) and higher for those who use hoses directly fitted on to water taps. Also, it is apparent that people in Kuwait are disturbed most by the colour of their household water. That is why a high percentage of the people surveyed use bottled water for drinking rather than tap water.

As was expected, households that consumed a large quantity of water in Kuwait were large in size, had high incomes, employed servants and drivers, and lived in villas. In addition, the analysis of correlations indicated that, in order of importance, the type of dwelling, the dwelling (house) size, clothes washing, personal washing/bathing, the size of the family, the income, and the number of cars all positively and significantly contributed to daily water consumption in Kuwait.

Total annual water consumption in Kuwait is predicted to reach 1.37 billion imperial gallons (6.23 million m^3) by 2010. However, according to the upper limits (95% confidence limits) of time series analysis, this figure could be as high as 1.5 billion imperial gallons (6.82 million m^3). This represents an increase of 25.5% to 31.9% over the current consumption rates. Such an increase would definitely add constraints to the budget.

Public awareness and education programmes – perhaps the most important and necessary factor for an efficient water management system in the State of Kuwait – conducted by both the government and public/private interest groups can help to promote source reduction. Information flyers, booklets and 'home water guides' can provide the consuming households/industries with extensive lists of suggestions for reduction in water consumption. The educational programmes should strongly emphasize the negative health and environmental impacts of high water generation and poor water management.

In order to further enhance demand control measures and users' responsiveness, municipal water tariff schemes should be the subject of an intensive study and evaluation with a focus on the optimality of the tariff structure and full cost recovery. The water rates charged throughout the country are very low. In view of the rapidly increasing cost of water supply schemes, inflation and so on, the above rates still seem to be unreasonably low. The increase in tariff rates on the basis of metered consumption for the entire population is essential for water conservation and financial sustainability. Consideration must be given to an incremental block tariff so that customers receive clear price signals to conserve water. Targeted subsidies can be maintained for a particular segment of the population below a certain income threshold in order to avoid excessive financial burdens on the poor. While it is possible that high oil prices could persist and result in significant revenues over a sustained period in the future, a major question remains as to whether it is wise to proceed with expenditures on excessive water use against the alternative of allocating the resources involved to the development of the non-oil sector and the creation of employment opportunities for newcomers in the job market. The reduction of subsidies for water services and the reallocation of the resources saved towards non-oil activities would go a long way in reducing wasteful use, strengthening fiscal discipline, insulating the economy from trade shocks, creating jobs and ensuring inter-generational equity in the distribution of the wealth derived from oil.

In addition, the water authority should advise consumers on how to use more of the brackish water for their daily chores, such as irrigation, landscaping, household purposes, livestock watering and construction works. Furthermore, they could also make a separate network of brackish water for toilet flushing. Perhaps the water authority should have two different water rates, one for fresh water and a lower one for brackish water. By the same token, the water authority should study the reduction in the volume of water consumption for personal washing and bathing, by replacing conventional sprays (taps, shower heads etc) with ones that could reduce water flow.

The Ministry of Energy should seriously think of reusing wastewater treated effluents. In many places around the world, secondary treated wastewater is used for irrigation. However, tertiary treated effluents are produced in Kuwait and such high quality effluents can be used for irrigation without restriction (Alhumoud *et al.* 2003). Alternatively, the effluent could be discharged into artificially constructed wetlands, which may represent a viable option. In addition, the cost of producing tertiary effluents is very low compared with the cost of producing fresh water in Kuwait. It cost less than KD0.6 (US$2.04) to produce 1,000 imperial gallons (4.546 m^3) of tertiary treated effluent compared with KD3.21 (US$11.00) per 1,000 imperial gallons (4.546 m^3) of fresh water.

ACKNOWLEDGEMENTS

The author is very grateful to the Ministry of Energy, Kuwait, for data collection and for its support. Also, the author would like to thank the distinguished reviewers of the journal for their comments and suggestions.

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First received 16 January 2007; accepted in revised form 21 August 2007