AN EVALUATION OF THE MAIN FACTORS AFFECTING FUTURE MUNICIPAL WATER DEMAND FORECASTING IN KUWAIT

تقييم العوامل الأساسية التي تؤثر في مستقبل احتياجات المياه في دولة الكويت

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ملخص البحث :

تعتبر ندرة المياه أكبر مشكلة تعاني من دول المناطق الصحراوية والتي تعتبر الكويت نموذجا مثاليا لها .
في هذا البحث تم دراسة وتحليل العوامل المؤثرة علي طلب المياه في الكويت والتي تشمل كل من العوامل الطبيعية والاقتصادية والاجتماعية والتقنية .
لقد تم إنشاء أربعة خيارات مستقبلية تمثل التوقعات المختلفة للطلب علي المياه وعلاقة ذلك النمو السكاني المستقبلي للمقارنة والتحليل وذلك حتي سنة ٢٠٥٠م .
أن تحليل الخيارات المقترحة لطلب المياه أوضحت أن البلد لن تستطيع تلبية الطلب علي المياه إلا إذا تم السيطرة علي زيادة طلب المياه اليومي للفرد وكذلك السيطرة علي زيادة النمو السكاني في آن واحد .

ABSTRACT

The scarcity of water is considered the most challenging problem that is facing the countries in the arid regions, in which Kuwait is a typical type of these countries. The future estimation of municipal water demand in such a country is a critical factor for water resources planning and development. This water demand forecasting is an essential for the determining of the type, size, location and timing of the required improvements and developments of water resources system.

In this research the distinct features of main factors affecting Kuwait municipal water demand are discussed and analyzed thoroughly to find an appropriator value representing the per capita water demand in the future , these features include climate , economical , sociological and technological conditions.

The time series statistical data for the last years published by the ministry of electricity and water that cover many aspects of water (ex., production, consumption, projects) has been utilized and extended to represent four different municipal water demand alternatives for comparisons and analysis.

These alternatives based on the assumed prevailing future conditions, affecting the municipal water demand in order to estimate the future municipal demands that the state of Kuwait water security plan must satisfied. The analysis of the proposed alternatives showed that the country will face severe municipal water shortenings unless dual reduction and control of both the population growth and the per capita water demand rates are effectively applied.

Keyword : future water demand, estimating water demand, factors affecting water demand

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INTRODUCTION

The water production capacity in Kuwait has increased from 3 million gallons per day (mgd) in 1957 to 336 million gallons per day (mgd) in 2005 (ministry of electricity and water statistical year Book 2005), to satisfy the increasing water demand resulting from rapid population and an increase in the per capita consumption. Accordingly, the per capita consumption also has increased from 12 imperial gallons per day (gpd) to 110 (gpd) for the same period. However, it is known that the 1957 water supply system was imperfect and of low efficiency when compared to the new system, such that a large amount of water is being wasted in transport between the production stations and the consumers. This could mean that the earlier estimated per capita consumption is overestimated, since at that time most consumers got their fresh water from the filling stations where most the waste is attributed.

The study of the time series statistical data published by the ministry of Electricity and water, which cover many aspects of water and related subjects (e.g., production, consumption, projects), identifies the demand-supply relationships for different purposes at different times. Even though water production in Kuwait has increased by large proportions, this increase can not match the larger population growth, and that has made the per capita water consumption decrease for a number of years.

Although the per capita consumption of 110 gpd in 2005 represents only the indoor household uses, it seems to be comparatively low if local factors are taken into account such as, climate, standard of living, prices, water resources management and people's habits.

For water resources planning, the quantity of water needed in the future can be estimated based on per capita demand that the water system must produced while satisfying the economical ,sociological ,environmental, and technical constraints (Peterson, M. 1984). This will give an acceptable figure assuming a fair knowledge of the different water uses in the study area. Residential water demand could be estimated on the basis of units per household or dwelling, particularly if a metered system is used. This would give the total water withdrawal for a specific period for each household unit. But the unmetered dwellings peak demands should be evaluated on a prior basis because this usually has strong effects on the whole water supply system.

If the per capita approach of estimating future water demand is selected by the planner or any authority responsible for water resources development, population projections must be estimated first using available projections. Therefore, the per capita value of water demand must be approximated based on the available data and the most probable variables which affect the water demand in the present and future, then multiply this value by the projected population.

Howe (1968) made one of the most important early studies on residential water demand, by using desegregated data collected between 1961 and 1966 by the Johns Hopkins University in Baltimore, Maryland. These studies have been resulted in the development of an applied forecasting model by Hitman Associates of Colombia, Maryland (1969).

THE MAIN FACTORES EFFICTING MUNICIPALE WATER DEMAND

For the water demand estimation in Kuwait, the most influential factors controlling the amount of water withdrawal per person or per dwelling will be discussed and analyzed thoroughly to find the most representative value the for per capita demand. These factors will include climate, economical, geographical location, sociological, and technological conditions.

(a) Climate conditions

This factor strongly affects, both indoor and outdoor (e.g., lawn and sprinkling) water demand. There is a significant correlation between climate factors, such as temperature and rainfall, and the amount of water demanded for a specific period. Water demand is directly proportional to the regional temperature and inversely to the amount of rainfall. Kuwait is located geographically in a desert-like region, which is characterized by a long, hot summer with no rain and a short, cold winter with little rain. As a result of these harsh weather conditions, water demand in Kuwait is considered to be one of the highest when compared with other regions due to this important factor.

(b) Economical conditions

Many researchers have demonstrated that water demand is a function of the economic status or living standard of the users. Saunders and Warford's (1976) found that water demand increases with a raise in the family income and with the value of the living dwelling, which has been used for some studies as the family income indicator. In this study they found that population and average income have the greatest effects on residential water demands, but they did not include the other important variables as climate, geographical location, age of the city, and average lot size.

Therefore, with a higher living standard and a good economic status, the family can use more water-consuming equipment and facilities within their homes and for the larger open areas around the homes with possible indoor family swimming pools. The type of housing (e.g., single unit, townhouse, high-rise building), usually controlled by the ability of the family to purchase the desired type, affects the amount of water required for different uses. For example, the sprinkling and watering require less water with high- rise buildings than with single dwelling units.

The Kuwait economy is strongly dependent on oil revenue, which constitutes amount 90% of the total income. Also, the per capita annual income in Kuwait, estimated in 2003 to be around 21,000. $ (ministry of planning 2003) is considered one of the highest in the whole world.

As a result of this high oil revenue, Kuwait has developed one of the most comprehensive welfare states in the world. It includes free education, housing, health care, and large employment benefits. The sales value of a residence can nit is used as a family income indicator in the case of Kuwait, since the government ensures suitable and appropriate housing for all Kuwaiti families regardless of their income. In this case, the type of housing and the water consumption equipment included in each house are the determinant factors for the amount of water needed for all purposes.

However we can assume with high confidence that most of the people in Kuwait, especially the Kuwaitis themselves, prefer, under any condition, to

live in a private, single dwelling, even if there is a large difference in the prices between these single units and the multi-unit dwellings. This is due to the conservative culture and traditions that still predominate the way of living, in spite of all the changes which have occurred in the society in the last 40 years.

The government houses are built according to the most modern building specifications and are equipped with large water-consuming facilities such as toilets, baths, washing machines, and sprinklers. In addition to this equipment, all the housing units are metered and connected to new sewage systems.

The residents are not charged for the water supply network system or the sewage system. All charges are paid by the government. In addition, the residents pay only part of the total cost of the water they use due to large government subsidies to the government owned and operated water production industries.

In essence, the economical factors affecting water demand in Kuwait are responsible for increasing the demand and encouraging more water uses than necessary. These economical factors create an ideal environment in which any conservation measure will not be accepted by the consumers and the per capita demand should be expected to increase with time. Therefore, to select a figure for the per capita water demand in Kuwait on that basis and under the control of the prevailing economical condition, this figure should be one of the highest for each different use, especially for municipal water demand.

(C) Sociological Condition

Social behavior is strongly correlated to the regional economic condition, to the point that most social changes are considered a consequence of economical situations. The quantities of water demanded for water supply, sewage collection, and waste water treatment and disposal, vary considerably from one region to another as a consequence of the differing characteristics of social activities, level of education and habits.

Social factors affect both the quantity and the uses of water demanded in such a way that the quantity of the water demanded is related to the willingness of a person to pay for extra water , while the uses are related to the person's habits and culture

Several studies have concluded that family size which is mostly affected by education is the most influential factor affecting the per capita consumption, and this per capita use varies inversely with the number of persons in a dwelling unit. In addition, the per capita water consumption increases with the level of education of the household, and decreases as the size of the housing unit increases (whiteford, 1972).

(D)- Technological Conditions

The state of Kuwait is producing high quality distilled water from its large scale distillation plants and pumps it to the consumers through water distribution networks. This water is potable with high hygienic standers passes through several chemical and bacteriological tests to assure the water quality from the source to consumers. In addition the water is distributed to the consumers under a high pressure through the water distribution networks which is resulted in large quantity of water wastes.

These technological advances in water quality and water distribution net works high pressure will increase the municipal water demand in Kuwait in the future.

After discussing the important factors which control the type and pattern of water uses in general, with particular emphasis

on the most important ones, a specific policy for the estimation of water demands in Kuwait can be generated. In the case of Kuwait, reasonable time series data exists regarding the total water production and demand from which per capita total water consumption can be derived. A base year estimate should be found, which can be extended to the future to get a total demand for the planning time assumed.

PROBABLE FUTURE MUNICIPAL WATER DEMANDS SYSTEM ALTERNATIVES DESIGN

A probabilistic forecast will be used for estimating the future municipal water demands for the state of Kuwait in order to produce a range of future alternatives for the decision making process.
These alternatives depend on many important factors such as the level of confidence given to their probability values, the quality of available data, the number of explanatory variables, and the time and budget available to the forecaster.

The probabilistic approach for estimating the future municipal water demands is required especially when the forecasting errors have significant impacts from the point view of cost, and the uncertainties associated with long –rang estimates which are actually the case for water resources planning and development.

The estimation of future municipal water demands contains many uncertainties due to the long-rang time frame that will make some of today's assumption far from actual values in the future. .. Therefore in order to overcome this problem we will develop deferent future municipal water estimation alternatives using the available data under different future assumptions and scenarios, with the population growth and municipal water demand rates as the main independent variables.

Future municipal water demands estimation alternatives will be designed according the following assumptions for the population growth rates and the associated municipal water demand growth rates in order to find the quantity of municipal water the state of Kuwait must produce to satisfy its population future water needs.

The first alternative is based on the assumption that the recent population and municipal water demands rates will continue at the same level without any changes Fig. 1. The second alternative is based on the assumption that the government of Kuwait will apply new immigration rules to control the population growth rate especially with the expatriates, while the municipal water demands rate will continue at the same today's rate Fig. 1. The third alternative is based on the assumption that the government of Kuwait will apply very restricted conservation measures to substantially decrease the municipal water demand rate, while the population growth rate will not change Fig.2. The fourth alternative is a promising one which depends on a substantial control of both the population growth rate and the municipal water demand rate Fig.2. It is very important to mention that Kuwait total population has reached almost three millions people by the year 2005,in which only one third of them is Kuwaiti citizens while the rest is expatriates who come to the country for works(Ministry of planning, 2005).

MUNICIPAL WATER RESOURCES CURRENT STATUS IN KUWAIT

The four future municipal water estimation alternatives design for the state of Kuwait will include the following municipal water resources current status as a supportive evaluation criteria and guidance.

(1) The per capita average consumption of fresh water has been increased from 12 Imperial gallons per day in 1957 to about 110(gpcd) in 2005. This figure represents only the indoor household uses, since Kuwait depends on tow separate water supply network: one for fresh water and the other of lower quality (brackish) water for outdoor uses.

(2) The average per capita consumption of brackish water has been increased from 16(gpcd) in 1957 (at that time only a small fraction of the population had access to this water) to 60(gpcd) in 2005.

(3) The fresh water network distribution system covers metered and sewage areas, while the brackish water is distributed on the basis of a flat rate.

(4) The pressure within the distribution systems is maintained at high levels in order to ensure enough water reaches the high-rise buildings.

(5) Single dwelling units, rather than high-rise buildings, are preferred by the people in Kuwait.

(6) Large quantities of water are used for gardening in the residential areas, in response to the natural scarcity of green spot in the country.

(7) High water quality from desalination plants will supply the country water demands at a subsidized price.

The future water demands depend to a large extent on the available historical data and ability of the forecaster to project these data in to the future, which in turn depends on the validity of the assumptions made for the future. In the case of Kuwait, good information is available for the water production and consumption for a long time period (1957-2005). The extension of these historical data by the extrapolation methods in to the future is found to be useful for estimating future water demands.

Future conditions that have an effect on water demands in Kuwait and must have a major consideration in the design and analysis of the future municipal water alternatives include the following.

(1) Family size will decrease while the number of houses will increase.

(2) As long as economical conditions do not drastically change, the number of water consuming machines and equipment in houses will increase.

(3) The number of toilets, baths, and water taps in each household will not decrease along with the decrease in family size.

(4) The trend to single family units will continue according to the government's plans to build new cities with all single units.

(5) There will be no significant water-use restrictions placed on the consumers by the government, (first and third alternatives only).

(6) All new houses and buildings will use meters and be connected to the public sewers.

(7) No significant climatic changes will happen within the planning time range.

(8) The above assumptions certainly will result in an increase in the per capita water uses.

Table 1. Alternatives comparisons for future population and municipal water demands
Population in millions (M), Municipal water demands in million gallons per day (mgd)

Year	First alternative		Second alternative		Third alternative		Forth alternative	
	Pop. (m):	Water (mgd)	Pop.(m);	Water(mgd)	Pop.(m):	Water(mgd)	Pop.(m):	Water(mgd)
2005	2.94	336	2.94	336	2.94	336	2.94	336
2010	3.08	339	2.88	317	3.08	316	2.88	294
2015	3.176	349	2.85	314	3.176	326	2.85	291
2020	3.37	370	2.81	309	3.37	346	2.81	287
2025	3.60	396	2.79	307	3.6	346	2.79	268
2030	3.93	432	2.76	304	3.93	380	2.76	265
2035	4.21	463	2.68	295	4.21	404	2.68	257
2040	4.57	502	2.62	288	4.57	439	2.62	252
2045	4.72	519	2.58	284	4.72	453	2.58	248
2050	4.96	546	2.54	279	4.96	476	2.54	244

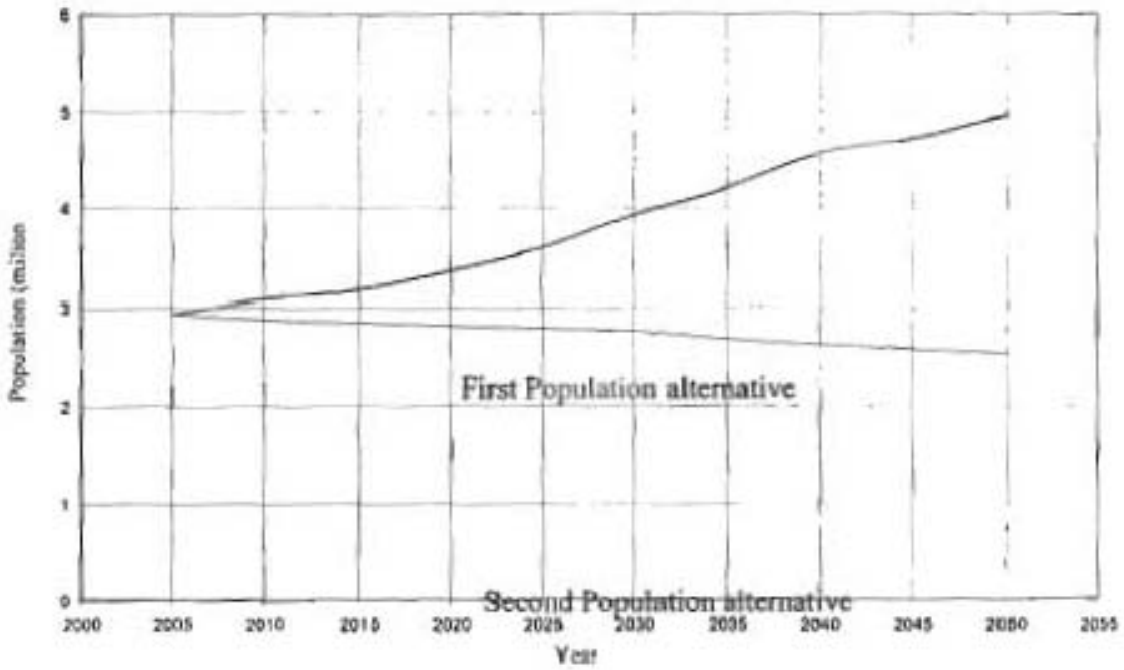

Figure 1. Future Population Alternatives

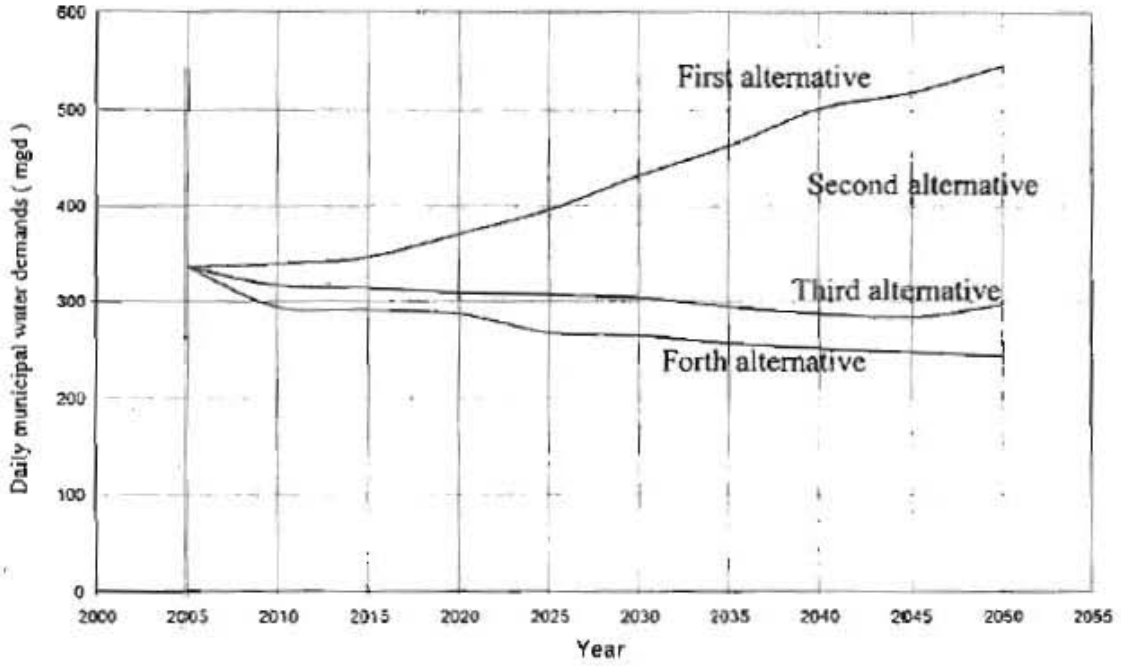

Figure 2. Future municipal water demand Alternatives

CONCLUSIONS

It is concluded from the analysis of the probable future municipal water alternatives that the population growth rate is a very effective controlling factor on future municipal water demand in such a way that the water resources development will not satisfy the future water needs under the recent population growth rate. The derived population growth rate from the available historical population data is comparatively very high for both the national Kuwaitis and the temporary immigrants who came to the country as skilled and unskilled labors for works.

The first alternative (base alternative) showed that under the present population growth rate and using the per capita water demand of the year 2005 the daily municipal water demand will be very high that the country will not be able to satisfy unless large numbers of new costly desalination plants have constructed. In addition this alternative showed that even with a reduced per capita water demand, the daily municipal water demands will still very high for the future which can not be satisfied with the available production capacities of the country.

The second alternative which is based on the assumption of a government controlled population growth reduction for both the national Kuwaitis and the incoming immigrants gives good results for the municipal water demand which is

reduced to an affordable quantity using the present municipal per capita water demand rate.

The third alternative showed the strong effectiveness of high population growth rate on municipal water demand in which the significant of the per capita water demand reduction will lose its influence due to the high population growth rate.

Finally the most promising alternative for municipal water demand policy is the fourth alternative in which both reductions are applied for the population growth rate and the municipal per capita water demand rate. This is resulted in an optimum alternative for municipal water demand that can be achieved easily with the available water resources production capacities and also allow more water to be saved for future needs.

The country certainly will face a sever shortages of its municipal water before the year 2025 under the assumed conditions, unless another means of management and utilization of water resources have been developed especially with the first and third municipal water demands alternatives.

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