WATER DEMAND MANAGEMENT USING A CONSERVATIVE IN-HOUSE POTABLE WATER DISTRIBUTION SYSTEM

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ABSTRACT

Random field survey was conducted to specify the in-house potable water distribution systems used in Riyadh city. A questionnaire was designed for this purpose with three different groups of questions. The first group deals with the system properties and number of outlets, the second group covers the behavior of residents with the system and the last group has general questions about the house and the resident.

Survey results show different usage behaviors of the system and the main elements of the house and identify four common systems in use.

Water consumption of the different systems was determined using computer program based on number of assumptions obtained from the survey. Results showed that, there are a great variation on the consumption among these systems having a consumption range between 40 and 259 m^3/month. System number three has the lowest water consumption for all cases while system number one, which is the most popular system, has the highest water consumption.

A conservative system was suggested which is similar to system number one on the way of distributing the flow but with different pipe sizes. This system provides low consumption rate compared to other systems in most cases with a maximum consumption rate less than 52 m^3/month in extreme conditions and provides the required hydraulic conditions.

Key Words: Pipe networks, water conservation, water demand management, water consumption

INTRODUCTION

In Saudi Arabia, agriculture is considered the main water consumer with about 90% of the annual water budget, while industrial and municipal consumption some in the second rank. Most released publications do not distinct between industrial and municipal uses. Municipal consumption includes several categories including house hold uses, commercial, public utilities such as mosques, schools and hospitals. These constitute about 6% of the annual water budget. Although it seems small percentage, but it has an extreme importance as it must satisfy high quality standard and such quality of water is scarce in nature on the international level.

During the last three decades, Saudi Arabia, witnessed a fast and amazing development in various fields, where cities broadened and endorsed hundreds of villages, commercial and industrial activities are increased. This was accompanied by an improvement in the individual income and hence the rise in the living standard which led to an increase in the population. In which population jumped from 7 millions in the year 1974 to more than 22 million in the year 2000. This huge increase in population required an increase on water demand on various fields and pronounced more on municipal purposes. Water demand for municipal and industrial purposes increased from 510 million cubic meter in 1980 to more than 2.2 billion cubic meter in the year 2000, where the per capita was increased from 120 liters/day to 315 liters/day (Ministry of Planning : the seventh development plan [6].

Securing drinking water faces many challenges and difficulties which need exertion of extra efforts in this aspect by the government and awareness of the consumer, and the low annual rainfall rate and depletion of ground water are some of these challenges.

Cities, in the kingdom, depend on ground water, surface water or desalinated sea water for securing drinking water, and desalination provide 50% of drinking water in the kingdom, Al-Hosaine [4].

Riyadh City for example depends on ground water and desalinated water from the Arabian Gulf to secure drinking water. In which there are 136 deep wells and 30 subsurface wells in and near by Riyadh city, Aboabat [1]. Desalinated water was brought to Riyadh since the year 1983 from Al Jubayl plant, and the average delivered quantity was about 85 thousand cubic meters per day. And with the fast growth in the city the quantities delivered grows rapidly to reach the maximum capacity of Al Jubayl plant (830 thousand cubic meters per day). Desalinated water mixed with ground water at Alwasia well field and stored in six over ground tanks with a total capacity of 300 thousand cubic meters. Mixed water then pumped to the main collection stations in the city where sterilizing and chlorination took place before pumping to the network for distributed, SWCC [8]. Additional water field supply to the city from Alhenai well field is expected to complete in the near future, which has 65 wells with an expected production of 350 thousand cubic meters per day, Ministry of Agriculture and Water [5].

Recent studies showed that Riyadh City will face an increase demand on drinking water during the coming years due to the expected increase in the population and the limited water resources, Aldahmash [4], Alboardi [2] and ADA [7]. The per capita decreased from 500 liter per day in the year 1980 to about 258 liters per day in the year 2000, and if this rate is kept constant then Riyadh City will need an addition of two millions cubic meter per day in the year 2020, Alboardi [2]. This decrease per capita results from the increase of the population and not from conservation as the delivered quantity of waters was constant during that period.

OBJECTIVES

The present study is an attempt to determine and specify the in house systems used for distributing drinking water. And to assess the performance of these systems through the computation of discharges and hence the consumption rate of each system for similar conditions.

To satisfy the objectives of the present study, a random field survey was conducted for new build houses in the city of Riyadh. Visits to municipality of Riyadh and to a number of engineering offices specialized in the design of residential houses were took place to see the codes, instructions and maps required for designing in house drinking water distribution system.

Then a questionnaire designed for this purpose which contains questions about the distribution system in the house, pipe types, number of toilets and kitchens in the house. More than 300 forms were distributed on a random sample in Riyadh City for citizens living in independent houses (villas).

WATER DISTRIBUTION SYSTEMS

From the visits to Riyadh municipality and the engineering offices it's become clear that the in house distribution system for drinking water does not gain the necessary attention and it is not a requirement to get construction license. This situation led to the use of different types of networks which mostly satisfy the desire of the owner and the contractor capabilities and experiences. In general systems consist of sump tank, pump and overhead tank and vary in the way of distributing water to the different parts of the house from the over head tank.

From the field survey, the distribution of drinking waters in houses can be classified into four systems as follow:

System No. 1:

In this system, each element (element means toilet, kitchen, etc) of the house has an independent supply line (pipe of 1 inch diameter) from the overhead tank. Flow from over head tank is splitted to a number of outlets (pipes) equal the number of elements of the house through a horizontal pipe of 2 inch pipe diameter by means of tee junction and elbows.

This system is considered the newest one and it has many advantages such as control of supply and easy maintenance without affecting the other parts of the house, Figure 1, shows the elements of system no. 1.

System No. 2:

This system splits the house into two units, an upstairs and downstairs or ground level and first level. Each level has a separate supply line of 1 inch pipe diameter from the over head tank. Figure 2 shows the details of this system.

System No. 3:

This system considers the house as a single unit where water supply takes place throughout a single pipe of 1 inch diameter to all elements of the house, details of this system are shown in Figure 3.

System No. 4:

This system splits the house into two parts, front and back or right and left, where water supply takes place for each part throughout a single line of 1 inch pipe diameter, Figure 4 shows the details of this system.

RESULTS AND DISCUSSION

1. Field Survey Results

The questionnaire includes three groups of questions, the first group includes general information about the house and the residents, the second group discusses the characteristics of the network and the third group covers the residents behavior and the way they use the system. More than 300 questionnaires were distributed randomly on different districts in Riyadh City. Only 256 questionnaires were used in the study after elimination of incomplete forms.

The study sample showed that 78 % of the sample individuals know the water network system in their houses, and that more than 48 % of them use system no. 1, while other systems have close percentages with 15, 17 and 20 %, respectively.

Also the study sample showed that 60 % of the houses have 5 to 7 toilets and that 75 % of these houses have two toilets in the ground floor and two toilets in the first floor. Also sample showed that 63 % of the houses have a toilet in the upper appendix and that 85 % of the houses have a single kitchen in the ground floor

Results showed that the average number of people per house is 7 for 75 % of houses and that 45% of the sample use toilets for 15 minutes per day while 38 % of the sample use toilets for one hour per day and 33% of the sample uses toilets between one and two hours per day. Also results showed that 67 % of the sample uses 3 toilets at the same time while 14% of the sample uses four toilets at the same time.

2. Calculation of the Consumption Quantity

Hardy Cross method is one of the most common methods used for computation of flow rates and pressure losses in pipe networks. In this study this method was used for this purpose by the help of a computer program. The flow rates through these systems were computed based on the following assumptions:-

- an ideal villa having two floors and an upper appendix, the ground floor consists of 3 toilets and a kitchen, the first floor have four toilets and the upper appendix has one toilet.
- All taps and valves are fully opened and flow computed at the inlet to toilet or the kitchen.
- Local loss coefficients are constants for all systems and pipe lengths depend on the system used.
- Over head tank is located at 8 meters above the ground and water depth in the tank is 2 meters.

The consumption rate was calculated for each system based on six different assumed operating conditions as shown in Table (1).

Figure 5 shows the flow rate in liter per second for the four systems for the six operational types. The figure shows clearly that there is a big variation in the flow quantity for the different systems and that there is similarity in the performance of these systems for each operation condition, which means that the operating condition does not affect the preference of the systems. The figure shows that system no. 3 has the lowest flow amount while system no. 1 represents the highest flow amount in all cases. The effect of system on the consumption quantity was explained by computing the daily and monthly consumption rate assuming that the system will operate for 15 minutes per day according to the survey results. Figures 6 and 7 show the consumption rates, daily and monthly, for all systems under the different operational cases. These figures show clearly that system no. 3 is the best where the daily consumption rate of the house ranges between 1.342 and 1.432 cubic meters in the different cases, other systems are in the following order, system no. 2, no. 4 and no.1 at last. Similar results were obtained in the monthly consumption rate with consumption rate of 259 cubic meters for system no. 1 in the worst operation condition case, while system no. 3 has about 43 cubic meters at the same condition. This means that, homes with system no. 1 consume more than 6 times the consumption of homes with system no. 3.

Assuming that the average number of residents per house is 7 as given from the survey, the per capita consumption amount was calculated and given in Table 2, which shows that there are a huge variation on the daily per capita amount depending on the system type and the way it operates. A person who lives in a house having system no. 1 consumes at least 3 times more than those of system no. 3 consume. These results indicate clearly the effect of the system used on the consumption amount or the per capita rate and that awareness and feeling of responsibility may not be sufficient if the water distribution network does not help in that.

SUGGESTED CONSERVATIVE SYSTEM

Although system no. 1 has the highest water consumption rate compared to other systems, it has a number of advantages as mentioned above in addition to the pressure levels provided by this system which are required for most appliances in the house. Other systems, especially no. 3 has the lowest pressure level among the others which affect the performance of appliances and hence the satisfaction of the resident. Hence, system no. 1 was modified and redesigned so that it will provide the required pressure levels and reduce the consumption rate. After a number of trials, it was found that replacing the main distribution pipe by a 1.5 in pipe diameter and other lines by 0.5 in pipe diameter will give a significant reduction in consumption rate. This system consume between 14 m^3 and less than 52 m^3 per month under the different operational conditions. And the per capita rate range between 65 liter and 244 liters per day for the different operational cases. These results save more than 30% of the amount consumed when system no. 3 is used for all cases except the extreme case which is rarely occurred. Figure 8 shows the consumption rate for the suggested system and system no. 3. This system provides the required levels of pressure and reduces the number of fittings as most appliances use 0.5 inch diameter.

CONCLUSION

This study aimed to identify and assess the performance of the in house water distribution networks in Riyadh city. Field survey was used to do this through a questionnaire designed for this purpose. Questionnaire included questions about the system used and the main elements of the system and the way it used.

Survey results show that there are four common systems in use. Also survey results show the different usage behavior of the system and the main elements of the house.

Water consumption of the different system was determined using computer program based on number of assumptions from the survey results. Results showed that, there are a great different among these systems having a consumption range between 40 and 259 m^3/month. Results also showed that system number three has the lowest water consumption for all cases while system number one, the most popular system, has the highest water consumption.

A conservative system was suggested which is similar to system number one on distribution but with different pipe sizes. This system provides low consumption compared to other systems in most cases with a maximum consumption less than 52 m^3/month in extreme condition and provides the required hydraulic conditions.

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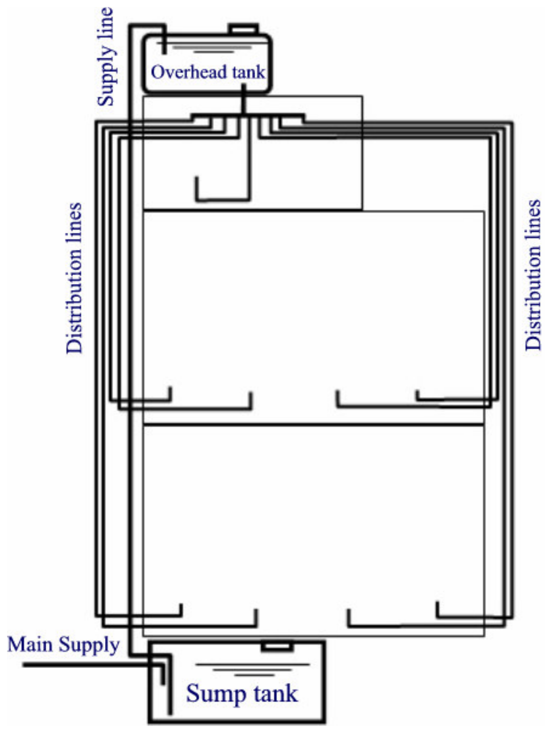

Figure 1. Schematic drawing of system no. 1

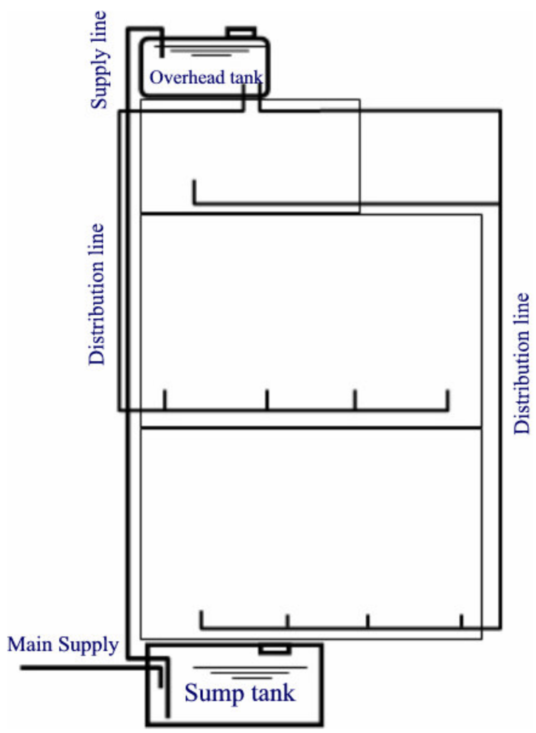

Figure 2. Schematic drawing of system no. 2

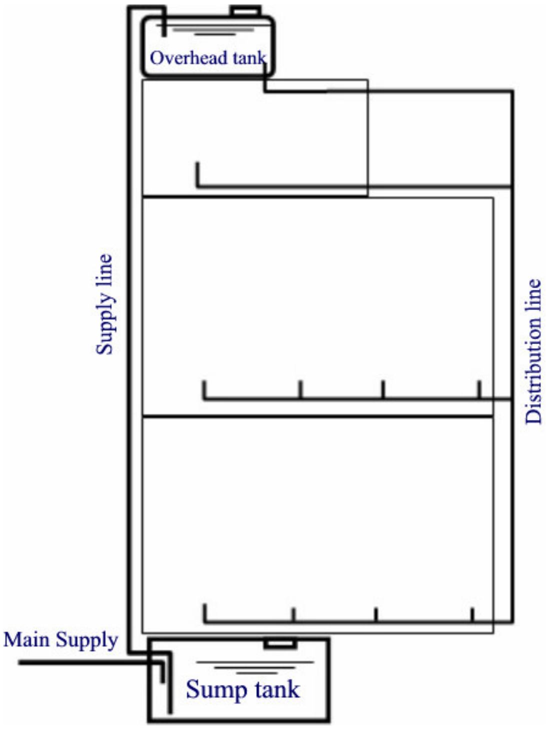

Figure 3. Schematic drawing of system no. 3

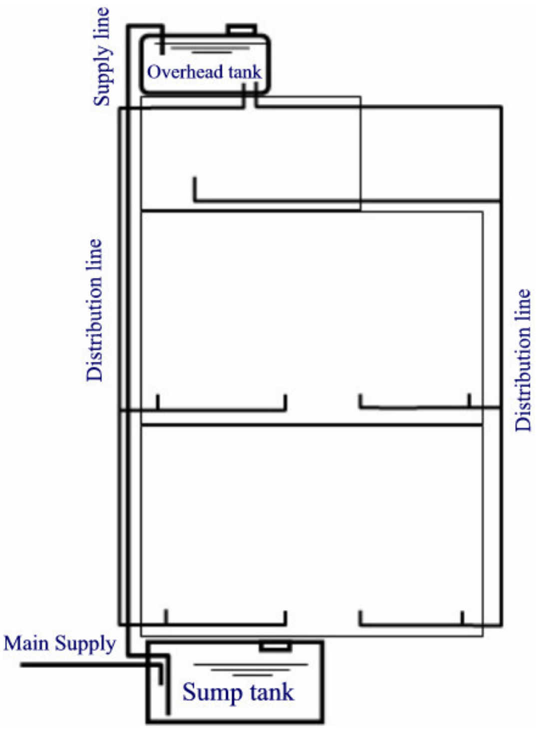

Figure 4. Schematic drawing of system no. 4

Table 1. Operation conditions for water distribution system

	Ground floor	First floor
Case 1	one toilet + kitchen	one toilet
Case 2	two toilets + kitchen	one toilet
Case 3	one toilet + kitchen	tow toilets
Case 4	two toilets + kitchen	tow toilets
Case 5	one toilet + kitchen	three toilets
Case 6	All element are working	

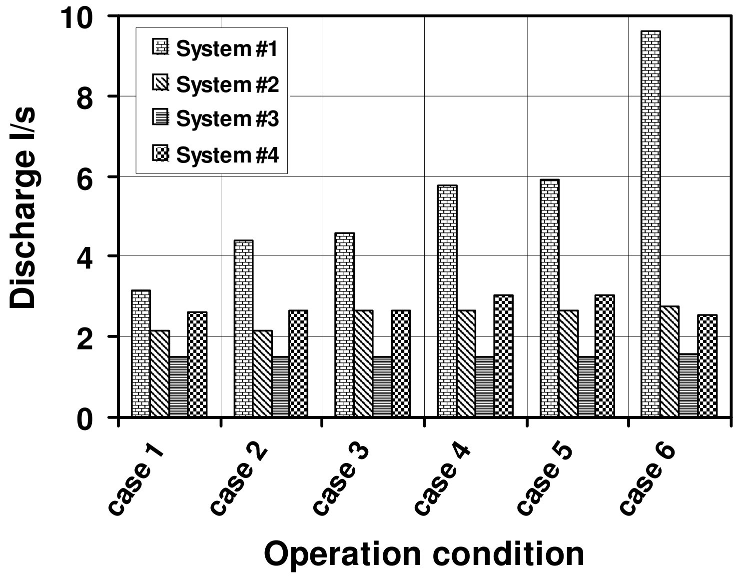

Figure 5. Discharge in the different systems at different operation conditions

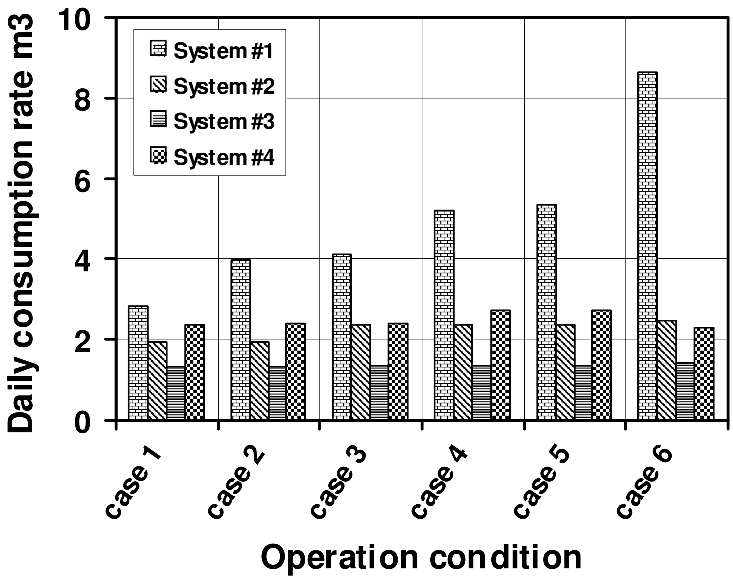

Figure 6. Daily consumption rates in m^3 for different operation conditions

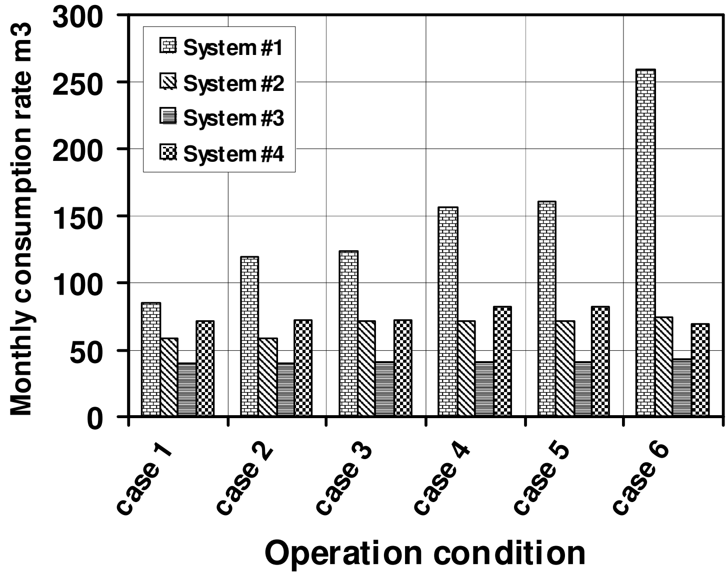

Figure 7. Monthly consumption rate for all systems under different operation conditions

Table 2. Per capita consumption rate in liter per day

System / Ope. Cond.	Sys. 1	Sys. 2	Sys. 3	Sys. 4
Case 1	406.8	275.9	191.7	336.8
Case 3	589.6	338.8	195	342.5
Case 6	1234.7	354	204.6	326.9

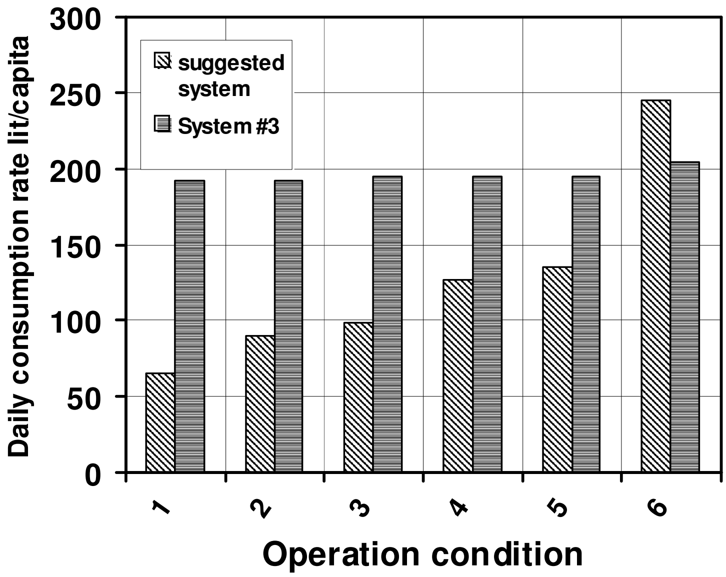

Figure 8. Comparison between the suggested system and system no. 3 at different operation conditions