

A Test of Harnessing Roofwater for Non-potable Uses at a Residential District in Hangzhou

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Abstract: Water demands are constantly increasing in HangZhou because of industrial development and increasing population. Hence, there is a continuous search for new sources and one such source is roofwater from high-rise buildings. In this paper the experiment of collecting the roofwater from the south spine of a residential district in HangZhou was done and utilising it for non-potable uses was discussed, too. A well-established simple input-output model incorporating a dual-mode system (DMS) of operation has been used so as to ensure that all the collected roofwater from an area of 18.75 m² is used only for non-potable purposes. The design parameters were optimized leading to a rainwater storage tank linked to the existing water tanks with pump cut-in and cut-out electrodes placed at depths of 1 and 1.5 m above the base of the tank that will ensure that the supply of water will always be available for the non-potable uses.

Keywords: Rainwater; Model; residential district; Collection

1. INTRODUCTION

In a limited land area of about 3068 km² HangZhou city has a population of 3.725 million and due to industrial development and increasing population, water demands are constantly increasing. On the other hand, the annual rainfall in HangZhou is about 1390 mm and some water areas are polluted. Hence, the water shortage has been found and augmentation of water resources and investigation of potentially new areas are on-going issues in HangZhou. Since many urban population lives in high-rise buildings, the roofs of such structures have good potential to act as catchments to collect roofwater at a high level and use it, preferably, for non-potable uses. The main objectives of this study are to review some computer models on roofwater collection, to select a simple model and using existing data to determine the optimum design parameters. The collected roofwater is to be used for the flushing of toilets and the proposed system is to be integrated with an existing potable water system by incorporating a dual-mode facility which will ensure the perennial supply for non-potable and potable uses.

2. METHODS AND MODELS

2.1 Models Developed in the Paper

Models have been developed which use rainfall, catchment area and yield to determine storage requirements. Such models have varied from simple deterministic types ^[1] to probabilistic ^[2] and stochastic models ^[3]. A simple input/output simulation model was

used ^[4] with a minor addition in the output side as follows:

$$Q_i = Ar_i - \{(E_i + b_i)A + D_i\} \quad (1)$$

where during any duration i (say, 20 min), Q_i is the available quantity (in say, m³), r_i the rainfall (m), E_i the evaporation (m), b_i the absorption (m), D_i the draw-off (m³) and A the catchment (m²) which is independent of i . Eq. (1) is applied to a known storage volume and the cistern will be empty or subject to spillage according as Ar_i is lesser or greater than $\{(E_i + b_i)A + D_i\}$. The main advantage of this model is that it can be adjusted to suit the durations in which data like rainfall, evaporation and absorption are available. This model has been used, for varying field conditions, over a period of time. In a study on the collection of rainwater from a bus park cum interchange ^[5], a simple computer program (NTURWCS.MK1) was written to calculate the optimum tank size required to meet the daily needs. In this program, as evaporation and absorption data were not readily available, suitable runoff coefficients were used as the runoff was being collected from both roofs and paved areas. In a more recent study ^[6], rain water from all the high-rise buildings in a housing estate having a typical average height of 12 storeys has been collected and stored at roof level. Using a DMS and a separate piping system, the collected roofwater is used only for non-potable uses thus also effecting considerable savings in energy costs.

2.2 Description of the Sites

Spread over an area of about 65 mou, the residential district lies in the south-eastern part of HangZhou. In

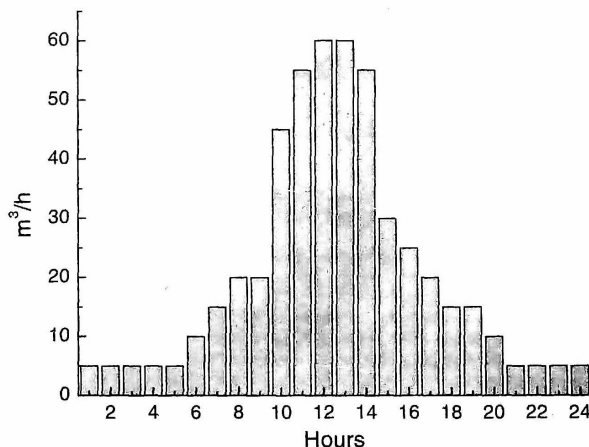


Fig. 1: Daily water demands

this area there are two buildings, one elementary school, and two canteens which lie around the north and south spines. Potable water, which is readily available, is pumped to two high-level tanks, which cater for the water requirements of the whole residential district. Water from one of these tanks is gravitated to the south spine where it is stored in a 15.0m x 6.5m x 4m deep distribution tank that consists of two inter-connected compartments. The water is then distributed by seven different pumps to constant head tanks located at the roofs of various buildings in the south spine. At the outlets in the distribution tank, eight sets of 24 hourly readings were taken and the consumption is as shown in Fig. 1. There is a wide variation in demand from 5 m³ at 21:00–5:00 h to a maximum of 60 m³ at 12:00 h. The average consumption per day was 500 m³. Continuous recording is done in a rainfall station in this residential district using a standard tipping bucket type rain gauge. The readings obtained covered a period of about two hydrologic years between 1999 and 2001. During this period, 35 water samples were collected at the roof level and tested immediately for relevant physico-chemical and bacteriological parameters.

3. RESULTS AND DISCUSSION

3.1 Proposal to Use the DMS in the Rainwater Tank and Select the Model

This experiment is confined to the collection of rainwater from an area of about 1,875 m² in the south spine. The approach in this study is to channel all rainwater into a new rainwater tank that shares a wall in common with the existing distribution tank. The distribution tank will be supplying water only for potable uses whereas the rainwater tank will meet all the demands for non-potable uses. The two water tanks will be separate units but they will be

inter-connected by a simple DMS such that when the rainwater tank is empty, potable water will be pumped into it to a pre-determined level and the water will be used for non-potable uses. It is ensured that the inflow pipe from the distribution tank is at least 15 cm above the top water level of the rainwater tank so that there can be no back flow. This separate system will ensure that there will be no intrusion of rainwater into the existing distribution tank besides which the dual mode of supply will be perennially operational. Due to the availability of hourly data, the model chosen is NTURWCS.MK1^[5] in which the basic inputs are rainfall data, size of storage tank, evaporation, absorption and the hourly demand. The output will be the rainwater collected, the quantity that overflows and amount of potable water that will be needed when the stored rainwater runs low. The program was run for different storage volumes by varying the pump cut-in/cut-out electrode levels that represent the bottom and intermediate levels respectively in the rainwater tank.

3.2 Optimum Length of Rainwater Tank

The rainwater tank was to be placed adjacent to the existing distribution tank. Initially a series of runs was carried out varying the volume of the rainwater tank. This was done by retaining the breadth and depth of the distribution tank (due to space constraints on site) but progressively increasing the length thus leading to larger volumes for the storage of rainwater. The results obtained are as shown in Fig. 2. It can be seen that when the rain overflow was reduced to zero, thus indicating full utilisation (or 100%) of the collected roofwater, the optimum length of the rainwater tank is 41 m. However, if the arrangements on site only allow a shorter length, some adjustments can be made widthwise ensuring that the volume of the rainwater tank is unaltered.

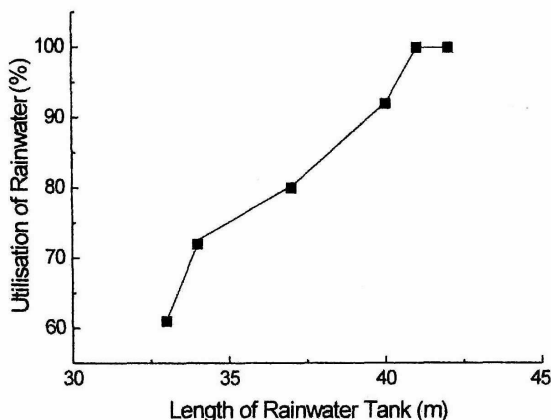


Fig. 2: Rainwater tank length analysis

Table 1: Water quality: rainwater, potable and hydraulic laboratory quality^a

Parameter	Rainwater	Potable water	Hydraulic lab
pH	4.2 (0.5)	7.0-7.5	7.3 (0.2)
Colour	8.6 (9.8)	<5	25.4 (31.5)
Turbidity	4.6 (5.7)	<5	40.5 (15.3)
TSS (mg/l)	9.2 (8.5)	240-400	8.5 (6.0)
TDS (mg/l)	19.3 (13.5)	—	387 (109)
Hardness as CaCO ₃ (mg/l)	0.1 (0.2)	20-40	31.4 (1.8)
PO ₄ as P (mg/l)	0.1 (0.5)	—	0.1 (0.1)
Total coliform ^b	91.5 (95.6)	0	1.5 (2.1)
Faecal coliform ^b	6.7 (8.5)	—	1.0 (0.1)

^aNote: Values are means and those in parentheses are standard deviation

^bMPN/100 ml.

3.3 Pump Cut-in/cut-out Electrode Levels and Rainwater Quality

Though the optimum volume of the rainwater tank ensures that all the collected rainwater is utilised, there is the need to determine the quantity of potable water that has to be pumped into it whenever it is almost empty. This corresponds to the bottom water level (BWL) of 1 m which is actually the pump cut-in level of the electrode. With this in mind, a series of runs was carried out to determine the relevant volumes to be used in relation to the number of cut-ins. The most suitable level for minimizing the use of potable water was determined to be at a height of 1.5 m, which corresponds to the pump cut-out electrode, or intermediate level of the tank. The transfer of water from the existing distribution to the rainwater tank is done by installing a pump having a capacity greater than the maximum water demand rates for non-potable uses. Such a DMS will ensure that the non-potable demands are met perpetually and, at the same time, there will be no intermixing of potable and non-potable water in the existing distribution tank, which will be dedicated to the supply of potable water. The qualitative analyses of the collected water samples are presented in Table 1. Also presented are the prevalent potable water standards in China and the quality of water, non-potable type, prevalent in the hydraulic laboratories in the residential district wherein

water is recycled. The collected rainwater has a generally high quality in comparison with potable water supply and the laboratory storage tanks except for pH and the total coliform counts. Treatment has to be carried out so that the pH is raised to the range of 7-7.5 besides which suitable disinfection has to be carried out, as it has been experienced in the past that such stored water has been the breeding ground for mosquitoes leading to dengue fever.

4. CONCLUSION

A simple input/output model has been used to arrive at an optimum size of rainwater tank, which will ensure that all the collected roofwater will be used for non-potable uses. The collected water has an acceptable quality for non-potable uses and it is recommended that provision be made to raise the pH and disinfect the water. The collected rainwater is directed to a separate rainwater tank that is linked to the existing distribution tank which only supplies potable water. The operation of both these tanks will ensure that potable and non-potable requirements are fully satisfied and, at the same time, the potable water will not come in contact with rainwater. This is effected by a DMS which will ensure that when the rainwater tank is considered to be empty at the BWL of 1 m, a pump is activated and potable water from

the distribution tank is transferred to the rainwater tank to the intermediate level of 1.5 m.

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