Water saving and runoff retention potentials of a rainwater collection system in a university building in Colombia

Économies d'eau et potentiels de rétention des eaux de ruissellement d'un système de collecte des eaux de pluie dans un bâtiment universitaire en Colombie

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RÉSUMÉ

Ce document décrit un système de collecte d'eau de pluie installé dans un bâtiment universitaire. Dans ce système, les eaux pluviales sont collectées sur le toit du bâtiment, puis utilisées pour satisfaire une partie de la demande de chasse des toilettes et des urinoirs, favorisant ainsi des économies d’eau potable. Le système a été équipé d'un système de surveillance qui a été utilisé pour enregistrer la consommation d'eau dans le bâtiment sur une période d'environ 5 mois. La consommation d'eau dans le bâtiment, ainsi que les données pluviométriques locales, sont utilisées pour calculer l'économie d'énergie et les rendements de rétention du système à l'aide de l'algorithme de rendement après déversement (YAS). Les résultats montrent que des économies d'eau allant jusqu'à 69% et une efficacité de rétention jusqu’à 60% peut potentiellement être atteinte dans le système.

ABSTRACT

This paper describes a rainwater collection system that has been fitted within a university building. In this system, rainwater is collected from the roof of the building and then used to satisfy part of the toilets and urinals flushing demand and thus promote savings of drinking water. The system has been fitted with a monitoring system, which has been used to record the water usage in the building over approximately a 5-month period. The water usage in the building, along with local rainfall data, were used to calculate the water saving and the retention efficiencies of the system by means of the yield-after spillage algorithm (YAS). The results show that water saving efficiencies up to 69%, and retention efficiencies up to 60% can potentially be achieved in the system.

KEYWORDS

Rainwater collection, Rainwater tanks, Retention, Water saving efficiency, Water conservation

1 INTRODUCTION

Rainwater tanks in urban areas supply water for low quality in-house uses and at the same time serve as elements of stormwater management systems. Roofs represent an important percentage of the large impermeable areas covered by cities, hence offering a significant possibility for rainwater collection (Villarreal, 2005).

Water in Colombia is still an abundant natural resource. However, widespread urbanisation and the consequent creation of large-scale centralised systems make local drinking water supply systems vulnerable to shortages and water quality deterioration. A total of 318 Colombian municipalities have been identified as having high probability of water shortage, 83% of which depend on superficial water for supplying drinking water, and about 8% uses natural groundwater (IDEAM, 2015). In Colombia, 20% of household water use is for flushing toilets (DNP Fonade, 1991). Collected rainwater can supply this use with many economical and environmental benefits. By capturing and storing significant quantities of stormwater for landscape maintenance and improvement in urban areas, peak demands could be reduced, water conserved, and many stormwater management problems mitigated (Villarreal and Dixon, 2005). The rainwater tank of a building at the National University in Bogota, Colombia, offers the possibility to analyse how rainwater may contribute to environmental improvement of an area. In this paper, the model yield after spillage (YAS) is used to investigate the performance of the rainwater system regarding drinking water savings and retention of stormwater volumes.

2 METHODS

2.1 Rainwater collection system at the School of Engineering, Universidad Nacional de Colombia

The university campus is in the central part of Bogota, Colombia (elevation 2600 m.a.s.l). The mean annual precipitation in Bogota is 1000 mm, being April-May and October-November the wettest periods of the year (mean monthly precipitation 140 mm), and February–March, June-August the driest periods (mean monthly precipitation 70 mm). The monthly average temperature is 15°C.

The university building object of this study was built between 1938 and 1942. As part of the refurbish works that were completed in 2015, a rainwater collection system was implemented in the building to supply the demand for the toilets and urinals and in this way promote savings in potable water. The rainwater collection system has 18 m^3 tank (built in reinforced concrete), which collects rainwater from the roof of the building (A = 1800 m^2, built in roof tiles). The rainwater collected in the tank passes through a sand filter and a chlorinator, and then is pumped to a combined water tank (treated rainwater and water from the mains); from there it is distributed to the lavatories of the building. In case there is no rainwater available in the combined water tank, the toilets and urinals are supplied with water from the mains. The building has several classrooms, two large auditoriums and several computer rooms, as well as administrative offices. According to the statistics of the University, for the 2018 academic year the daily occupation of the building varies between approximately 3900 and 5200 people from Monday to Thursday, while on Fridays is 1200 and on Saturdays is about 320 people.

2.2 Water usage

In order to know the demand pattern of the building's lavatories, an ultrasonic meter was installed (SPIREMT 280-R-DN40), through which real consumption data were obtained every 10 minutes. The measurement period considered in the present analysis goes from 03/16/2018 to 15/10/2018. The collected measurements were analysed in order to identify how the consumption varies for different periods of time. With this information, cumulative consumption curves were constructed for the different days of the week, as well as for the different weeks of the measurement period. Figure 1 shows, by way of example, the curve for Thursdays and in Figure 2 for the weeks of April. The variation in daily consumption was contrasted with the occupation information for those days, and in this way, it was possible to determine that the differences are due to the number of people in the building. On Fridays and Saturdays, occupation is relatively low since academic activities are scheduled until noon. For the measurement period, cumulative water usage for Monday to Thursday varies between 5.7 to 7.3 m^3 (with a recorded exceptional value of 10m^3), whereas for Fridays and Saturdays the values vary between 3.1 and 3.4 m^3. Weekly cumulative water usage ranges between 28.7 and 35.5 m^3.

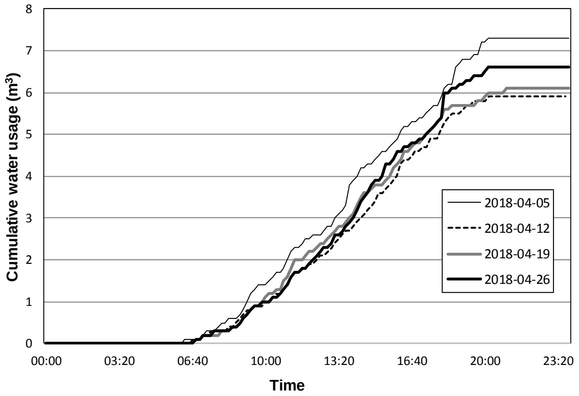

Figure 1. Daily water usage pattern in the building
(The figure shows an example for Thursdays in April 2018)

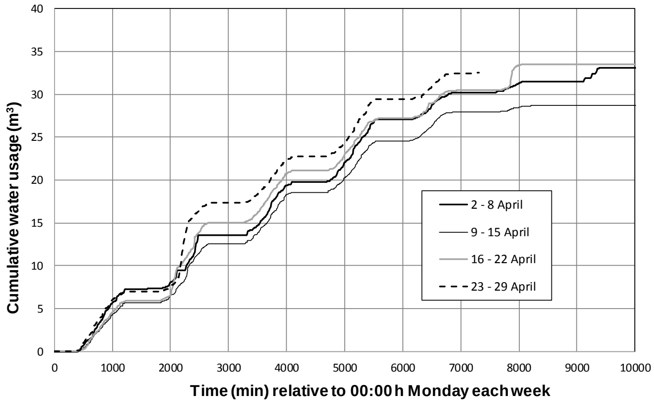

Figure 2. Weekly water usage in the building
(The figure shows an example for the weeks in April 2018)

Notice that both daily and weekly consumption curves show a regular behaviour. Accordingly, a characteristic consumption pattern was assumed for the analyses: one for each of the days of the week, and one for the entire week. Thus, daily, weekly and monthly analyses were performed to evaluate the water saving and retention performances of the rainwater tank.

As it has just been shown, weekly behaviour is very regular and for that reason it was decided to take this information to carry out analyses for several complete academic years (two whole academic terms). In this way, the performance of the system regarding water saving efficiency for four hypothetical academic years was evaluated, with the aim of considering the effect of the two rainy seasons which are typical for Bogotá, as well as the inter-annual variation of precipitation. The yearly analysis considered the months from February to May, including Easter week holiday, and from August to November, where the autumn week holiday was also taken into account. The months of January, June, July and December, were not considered for the analysis, since the occupation of the building in these months decreases markedly.

2.3 Rainfall records

For the period of analysis no simultaneous records of precipitation were available. Thus, it was decided to use the precipitation data (rainfall depths measured with a time step of 10 minutes, from 2007 to 2011) from one of the rain gauges of the network operated in the campus of the National University by and the Research Group in Water Resources Engineering (GIREH). From these records, daily precipitation hyetographs for the most intense storms recorded during the two rainy periods (March, April, May and September, October, November) were constructed to evaluate the retention of the stormwater tank. As for the water saving efficiency of the system, the entire length of the record was used to evaluate the performance of the system in a long term basis.

2.4 Modelling

To describe the operation of the rainwater store the *yield after spillage* (YAS) operating rule (Jenskins *et al*., 1978) was used:

$$Y_t = min\begin{cases} D_t \\ V_{t-1} \end{cases} \tag{1}$$

$$V_t = min\begin{cases} V_{t-1} + A \cdot R_t - Y_t \\ S - Y_t \end{cases} \tag{2}$$

$$Q_{Dt} = max\begin{cases} V_{t-1} + A \cdot R_t - S \\ 0 \end{cases} \tag{3}$$

where R_t is the rainfall during the time interval t, AR_t the rainwater runoff during interval t, V_t the volume in store, Y_t the yield, D_t the demand and S the store capacity; A is the roof area.

The *water saving efficiency* (E_{WS}, equation 4) of the system is a measure of how much mains water is conserved in comparison to the overall demand of the WCs and urinals, whereas the retention performance of the tank was evaluated using a *retention efficiency* (E_R, equation 5). E_R is a measure of how much volume of runoff is retained by the tank during a storm event as compared to the rainwater inflow volume.

$$E_{WS} = \left[\frac{\sum Y_t}{\sum D_t}\right] \cdot 100 \quad (4)$$

$$E_R = \left[1 - \frac{\sum Q_{Dt}}{\sum A \cdot R_t}\right] \cdot 100 \quad (5)$$

3 DISCUSSION

The analyses show that water saving efficiencies between 52 to 60% can be achieved in the building for the hypothetical academic years that were analysed. The results show that for wet years the E_{WS} can reach up to 80% for the water usage pattern identified for the building. Regarding retention efficiency, the results of the daily analysis (36 precipitation events considered) show an E_R between 40 and 69%, whereas the weekly analysis (25 precipitation events), E_R values were obtained between 31% and 52%. The results of the monthly analysis show retentions from 39% to 51%. Clearly, daily analysis give the highest E_R values; however, it must be taken into account that the tank was assumed to be empty at the beginning of the day. Notice that the range of E_R values obtained for the weekly and monthly analyses are about the same. For the analysis it was considered as realistic to assume water usage patterns; however, these results must be compared with data taken from simultaneous measurements of precipitation and water usage, as well as water levels within the tank. Actions are being taken currently to obtain the necessary data.

4 CONCLUSIONS

Important water savings and retention of rainwater volumes can be achieved in the system. Water usage plays an important role to achieve the effects of runoff retention since it rules volume availability within the tank during and between rain events. Similar results have been obtained in other research projects in different parts of the world (i.e., Burns *et al*., 2012, Campisano and Modica, 2014 and Burns *et al*., 2015). This study, however, differs from others in aspects such as type and size of building, occupation, and, of course, water usage patterns. The results of the analyses show that the rainwater tank fitted at the building has additional benefits apart from savings in potable water. The present study is a part of a long-term research project, which aims to investigate rainwater collection systems in Colombian cities and highlight the benefits of implementing them. These systems have the potential to contribute to a better management of rainwater in Colombian urban environments, and in this way become elements of a sustainable drainage system.

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