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Evaluation of water conservation and reuse: a case study of a shopping mall in southern Brazil

Eduardo H.B. de Gois*, Carlos A.S. Rios, Ricardo N. Costanzi

Universidade Tecnológica Federal do Paraná, Avenida dos Pioneiros, 3131, Londrina, PR 86036-370, Brazil

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A B S T R A C T

The main issues related to water conservation in urban centers are the increase in water supply cost, demand growth, pollution and differences in the distribution of water resources. Water conservation, the controlled and efficient use of water, includes both measures as reasonable means of water reuse. Thus, conservation practices are an effective way to meet demand and supply water to new activities and users without jeopardizing the supplying water bodies and preserving the natural environment. This study aims to examine the water management of a shopping mall, the use of rainwater harvesting combined with greywater reuse, to investigate the feasibility of these water reuse systems. For buildings in general, water loss is common due to leaks in the hydraulic and restroom equipment. These losses, which are caused by a high volume of water used and wasted in the system, are often the result of design errors, incorrect maintenance procedures and users' bad habits. In southern Brazil, where there is an abundance of rainwater, water shortages occasionally occur, particularly in the winter. One difficulty that appears on rainwater studies is the proper determination of rainwater volume that can be used to address water supply systems. In this work, the simulation method was used to determine this volume. Thus, simulations with the following variables: rainfall, catchment area and water consumption were performed. For mall's hydraulic systems, segmented alternatives are adopted. That is, focusing on the use of rainwater or greywater reuse. Other alternatives are underutilized due to sanitary issues, those are water from toilets and kitchen sinks. The adoption of greywater may be feasible if there is a significant flow of greywater to comply water demand for toilet flushing. The inspections made in this study found that the quantity of sinks was insufficient to supply an adequate amount of water to toilets and urinals. The greywater reuse system was found to be infeasible. Conversely, the rainwater harvesting system was entirely feasible and easily supplied water to all restrooms and contributed to the cooling of the air conditioning system with a short payback period. One of the challenges of this work was the need to compare the actual water consumption with a water consumption parameter used in buildings. Thus, a method that addresses the generation of specific consumption indexes for specific activity (like a mall) was used. The water consumption indices showed that this mall has a satisfactory water management program.

1. Introduction

Significant growth in population and changes in lifestyles due to rapid economic growth generate high water demands to supply agriculture, industry and cities (Anderson, 2003; Umapathi et al., 2013). These facts, combined with reduced water quality, increase water scarcity in urban areas, primarily in developing countries. Another aggravating factor is the change in water systems due to climate change (Zhang et al., 2009) and water shortages in combination with high levels of evaporation (Eriksson et al., 2002).

There is a need for a paradigm shift from the traditional 'supply-based management' to a 'demand management' approach. Demand management focuses on measures that create a better and more efficient use of limited supplies (Vairavamoorthy et al., 2008). Recently, one of the main concerns of companies, industries and institutions is the large amount of freshwater used in their building systems (Nunes, 2006).

* Corresponding author. Programa de Pós-Graduação em Engenharia Ambiental, Universidade Tecnológica Federal do Paraná, Avenida dos Pioneiros, 3131, Bloco E, Sala E106, Londrina, PR, Brazil. Tel.: +55 4333231133; fax: +55 4333156121.
E-mail addresses: baltrusch@hotmail.com (E.H.B. de Gois), segatto@sercomtel.com.br (C.A.S. Rios), ricardocostanzi@gmail.com (R.N. Costanzi).

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Water conservation and reuse creates many environmental benefits: reductions in wastewater discharges (on natural water bodies), water consumption, eutrophication and algal blooms (Anderson, 2003; Gregory, 2000).

This type of study identifies which activities or plumbing fixtures consume the greatest amount of water in a building. Water use can vary greatly depending mainly on culture, weather and standard of living (Proença and Ghisi, 2010). Among all opportunities for water conservation in building systems, stands out the following variables: saving devices, water use culture, environmental education and the water supply (Rainwater Harvesting and greywater reuse), being all related to water consumption minimization. Therefore this work aims to contribute with water conservation, analysis, evaluation, appropriate diagnostic and suitable solutions, specifically for malls. A key aspect analyzed was the conducted water diagnosis in the mall building system with rainwater use.

Rainwater harvesting has significant value in city planning, because it reduces urban sewage amount, also reduces water supply demand and decreases maintenance cost for urban environment (Wu and Chau, 2006).

Among other options (to reuse and save water), rainwater harvesting can play a key role in broadening water security and reducing environmental impacts (El-Sayed et al., 2010).

According to Domènech and Saurí (2011), new regulations and incentives that promote rainwater use are increasingly being developed worldwide. Countries such as Australia, Belgium, Brazil, Germany, India, Jordan, Spain, Sri Lanka and the United States are establishing or have already established rainwater regulations (for new buildings) and incentives (for old and new buildings) at the local, regional and national levels.

Rainwater is abundant in most parts of Brazil. In the southern region, the average rainfall is 1615 mm per year (Brasil, 1992). Studies conducted in the southern region of Brazil (Ghisi, 2006) and in the state of Santa Catarina (Ghisi et al., 2006) showed, respectively, a potential for freshwater savings of 82% and 69% on average for residential usage. Fig. 1 shows rainfall data for the city of Londrina, which is located in the state of Paraná, for the period 1976–2013 (1600 mm per year).

The aforementioned data indicate that there is an abundance of rainwater in the city of Londrina. However, the Londrina metropolitan area has suffered recurrent droughts recently, mostly during the winter when precipitation is historically low (Fig. 1), causing interruptions in the water supply.

Greywater reuse and rainwater harvesting have been studied worldwide to promote freshwater savings in residential and commercial buildings (Ghisi and Ferreira, 2007). Some researchers concentrated their investigations only on greywater (Abdulla and Al-Shareef, 2009; Mourad et al., 2011; Prathapar et al., 2005), others on rainwater (Cook et al., 2013; Moreira Neto et al., 2012; Rahman et al., 2012; Yoshino et al., 2014) and some on both systems for residential buildings (Ghisi and Ferreira, 2007; Li et al., 2010; Muthukumaran et al., 2011), but none has studied the combination of greywater and rainwater for commercial buildings.

As stated by Eriksson et al. (2002), there is an increasing interest in greywater reuse by industrial and developing countries. Greywater reuse decreases the final cost of wastewater treatment because there will be a reduced wastewater load passing through treatment plants.

In the present study, was evaluated the greywater reuse in conjunction with rainwater. The combination of these sources of water can be indicated in some situations, where water demand is greater than rainwater supply. However, the simultaneous use of these waters may cause some impediments in their uses, because the physicochemical characteristics of greywater, which require specific treatment to reach quality requirements.

The objectives of this research study were, first, to investigate a shopping mall's freshwater consumption and estimate the potential for freshwater savings by adopting water saving features, rainwater harvesting and greywater reuse and, second, to evaluate the feasibility of previously installed rainwater harvesting and greywater reuse system.

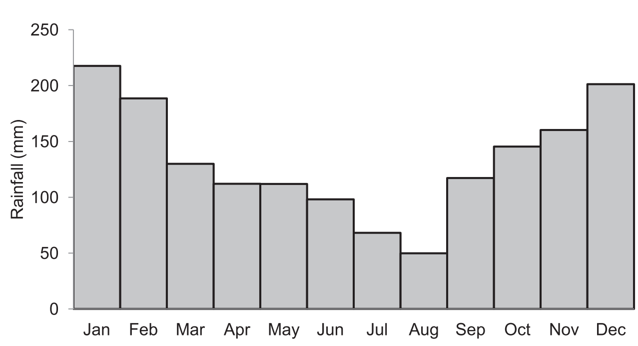

Fig. 1. Average rainfall for the city of Londrina over the period 1976–2013 (Paraná, 2013).

2. Methodology

2.1. Study location and building characterization

This study was conducted in the city of Londrina (Fig. 2), which is located in southern Brazil (latitude 23°22′ south and longitude 51°10′ west), in a shopping mall with a constructed area of 135.000 m^2 and a gross leasable area (GLA) of 82,000 m^2.

The facility, which has 299 stores, two food courts, six cinemas, bowling, fun centers and employs 2800 people. It was built in the early 1990s and has undergone three expansions, the last of which was a result of local legislation that installed a rainwater collection (850 m^2 roof area) and greywater reuse system, both for flushing toilet bowls and urinals.

There are seven sets of restrooms (seven female and seven male), but only five of these seven have hydrometers. Restrooms are numbered 1–7, and restroom number 7 already uses rainwater and greywater. All restrooms have *automatic*, sensor-*activated faucets*, except restrooms 2 and 4, which have manual *faucets*).

Employee restrooms were not quantified. The air conditioning system uses six cooling towers, which consume large amounts of water daily. However, it was not possible to quantify the volume of water that enters the system or the losses, as the system has various leaks.

2.2. Water management investigation

In this work was utilized the water consumption analysis methodology for buildings systems proposed by Nunes (2006). Others, water analysis methodology may be used, such as multiple criteria analysis and neural networks (Zhao et al., 2006; Muttil and Chau, 2007). However, the methodology used is specific for water systems in building facilities, having as an advantage the related indices generation for water conservation efficiency in buildings and is relatively easily to be applied, having as the results the system diagnosis and its evaluation as water conservation.

Visits to collect field data from the mall occurred in April and May 2013. Work was performed according to the steps presented by Nunes (2006):