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Water Savings in Buildings

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Enedir Ghisi

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CONTENTS

PREFACE

Water savings in buildings has been a matter of concern all over the world. Alternative water sources as well as water saving appliances have been studied by many researchers in order to try to promote water savings in buildings. Rainwater tank sizing and modelling, wastewater treatment and reuse, relationship between user behaviour and water savings, health issues related to water savings and environmental analysis of rainwater and grey water use in buildings are subjects related to water savings in buildings. Thus, the objective of the eBook is to put together some of these aspects by means of seven chapters written by renowned researchers.

Chapter 1, written by Andrea Teston, Barbara Müller Colasio and Enedir Ghisi, of the Federal University of Santa Catarina, Brazil, presents the state of the art on water savings in buildings in Brazil. The authors conclude that there is a high potential for potable water savings in buildings by using rainwater for non-potable purposes in Brazil.

Chapter 2, written by M. Ashiqur Rahman, Md Mahmudul Haque, Amir Ahmed and Ataur Rahman, of the Western Sydney University, Australia, focus on rainwater harvesting to reduce potable water demand in buildings in Australia.

Ilaria Gnecco and Anna Palla (of the University of Genova), and Alberto Campisano and Carlo Modica (of the University of Catania), Italy, wrote Chapter 3. It assesses methodologies for designing rainwater harvesting systems. The impact of European precipitation regimes on the management of rainwater tanks as well as on the influence of water demands on the performance of the system was also analysed.

Chapter 4 was written by Ghazaleh Vaseghi, Ilke Celik and Defne Apul (of the University of Toledo) and Steven Burian (of University of Utah), USA. It contains an approach for using multi-criteria decision analysis to study the tradeoffs of rainwater harvesting system designs.

Chapter 5, written by Asher Kiperstok and Alice Costa Kiperstok, of the Federal University of Bahia, Brazil, discusses the implementation of water saving programmes in institutional and university buildings over seventeen years in Bahia.

Chapter 6 was written by Cristina Matos Silva and Vitor Sousa, of the University of Lisbon, and Inês Meireles, of the University of Aveiro, Portugal. The performance of rainwater harvesting systems in residential buildings, a shopping centre and a university building in Portugal, covering different water use patterns and geographical locations, is shown in this chapter.

And last but not least, Cristina Santos (of the University of Porto), Cristina Matos (of the University of Beira Interior and University of Trás-os-Montes and Alto Douro) and Armando Silva-Afonso (of the University of Aveiro), Portugal, are the authors of Chapter 7. This chapter assesses health issues related to the application of water saving systems in buildings.

It is possible to observe that most of the locations presented in this eBook demonstrate that there is a great potential for potable water saving through the use of rainwater in buildings. Rainwater harvesting can increase water availability and, as a consequence, improve the population's life quality even in semi-arid regions, such as the Brazilian Northeast. However, the rainwater harvesting systems should be used in combination with other forms of water conservation for efficient water management in cities, such as water saving appliances and greywater reuse.

The more developed the country, the greater the water consumption in the buildings. For this reason, European standards recommend the conservation of water. Potable water savings is an ally for rainwater harvesting systems due to the retention time which is inversely proportional to the water quality in the reservoir. Asher Kiperstok and Alice Costa Kiperstok pointed out that waste of water is constantly driven by weak maintenance schemes and due to the fact that water is free to users of public facilities.

In Australia, according to M. Ashiqur Rahman, Md Mahmudul Haque, Amir Ahmed and Ataur Rahman, favourable regulations and public awareness have made use of rainwater as a significant alternative source of water in buildings. However, there is still room for improvement in systems by designing the project for greater efficiency. In Brazil, for example, there is still the need for more investments in national support programmes for water savings in buildings. But one of the most important programmes in the country is the programme called one million cisterns. This programme aims to provide a rainwater harvesting system for families living in areas where water is scarce or where the water utilities do not supply water.

As for methodologies for designing rainwater harvesting systems, Ilaria Gnecco, Anna Palla, Alberto Campisano and Carlo Modica explain the critical correlation between the rainfall event characteristic, antecedent dry weather period, and the system performance: the water saving efficiency is in inverse proportion while the water quality degradation (expressed as detention time) is directly proportional to the antecedent dry weather period.

The Utah case study presented by Ghazaleh Vaseghi, Ilke Celik, Defne Apul and Steven Burian in Chapter 4 shows three scenarios of reservoir positioning: (1) two reservoirs, one on the ground floor and one on the roof; (2) a reservoir on the ground floor; and (3) a reservoir on the roof. The conclusion suggests that using only one reservoir for rainwater collection and distribution is the most viable option, although they have not evaluated the impact of the need for greater structural support to withstand reservoir weight.

One of the problems that is still considered as an obstacle to the efficient use of water is health issues. That is why it is important to clearly state how to install a system and keep it safe and feasible, explaining what treatments are needed for rainwater and greywater to prevent human contamination.

Although the obstacles still met for the use of rainwater harvesting systems, such as population awareness, water waste and issues related to water quality, Cristina Matos Silva, Vitor Sousa and Inês Meireles have shown that rainwater is a relevant alternative for water conservation in Mediterranean countries, where water savings can reach up to 60% in most of the buildings studied.

I think this eBook will be a valuable resource to researchers, post-graduate students, undergraduate students, engineers, water utilities, environment agencies, industries, and many others interested in water savings in buildings.

I would like to thank all the authors who have contributed to this ebook, and the editorial team for their valuable work and completion of this eBook.

The views and opinions expressed in each chapter of this eBook are those of the authors.

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CHAPTER 1

State of the Art on Water Savings in Buildings in Brazil: A Literature Review

Andrea Teston, Barbara Müller Colasio and **Enedir Ghisi***

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Abstract: Water savings in buildings has become a matter of concern due to water demand increase in cities and to problems with water quality and availability. This chapter presents the state of the art on water savings in buildings in Brazil. Journal and conference papers, reports and theses published from 2003 to 2016 were reviewed. First, in order to show the main shortage problems faced by Brazilian people, the national panorama of water resources is shown. Then, papers about the use of rainwater, water quality, potential for potable water savings, investment feasibility analysis, greywater reuse and water-efficient appliances are also addressed. Water end-uses in buildings, environmental education, and national water savings support programmes are also presented. It was observed that there is a high potential for potable water savings in buildings by using rainwater for non-potable purposes in Brazil.

Keywords: Alternative water sources, Brazil, Environmental education, Greywater, National programmes, Payback, Rainwater, Sizing, Social acceptability, Water end-uses, Water-efficient appliances, Water savings, Water quality.

INTRODUCTION

In Brazil, the National Water Agency (ANA – *Agência Nacional de Águas*) conducts studies and plans that aim to support and guide the implementation of national policies and management on water resources.

In addition to being the country with the most voluminous river in the world (Amazonas), Brazil still shares the largest underground water source in the world with three countries (Uruguay, Paraguay, Argentina): the Guaraní Aquifer, which has an area of 1.2 km^2. The country is among the nine who owns 60.0% of

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Enedir Ghisi (Ed.)

renewable freshwater sources in the world. Considering only the American continent, Brazil has 34.9% of surface freshwater (Fig. **1**) [1].

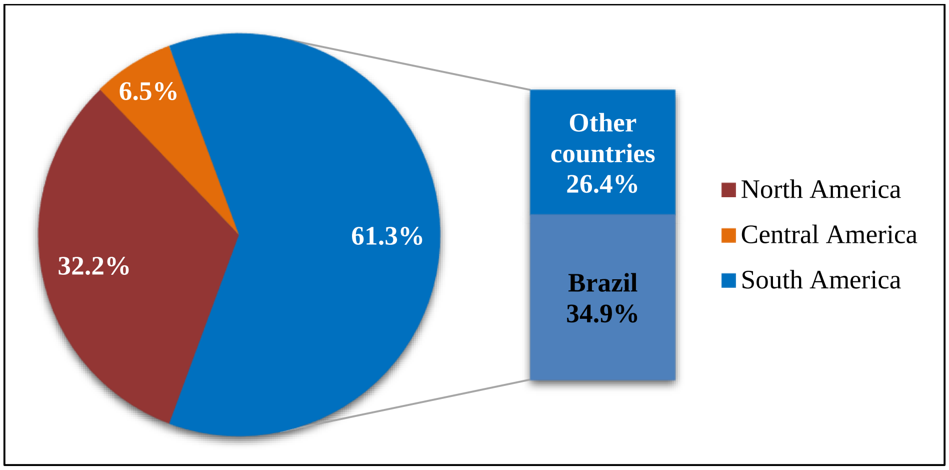

Fig. (1). Distribution of surface freshwater in the Americas [1].

However, although it has one of the largest water reservoirs in the world, Brazil faces shortages. Geographical and historical features justified this contradiction. The Brazilian urban expansion happened quickly, disorderly and recently; today 84.0% of Brazilians live in cities and most of them are located in regions where the supply of water is poor [2]. While the river basin district of greater scarcity shows availability of less than 100 m^3/s, in the Amazon River basin the availability reaches the flow of 74,000 m^3/s [1]. That is, the Amazon region, which has 69.0% of the water resources in Brazil, contains only 8.0% of the population, while the Northeast has 28.0% of the population and only 3.0% of the water resources [3].

In the Brazilian north-eastern semi-arid, water availability is an obstacle for the social and economic development of the rural population. The water availability is characterized by dry and rainy periods, and some regions have an annual rainfall of less than 200 mm. Most of the population live in this region collecting water from alternative sources (generally lakes and ponds) because they have no access to public supply. These sources present a serious risk to the health of the population, contributing to the maintenance of endemic cycles, with high infant mortality [4].

According to the historical series, the largest amount of dry records happens in the Northeast, followed by the southern region, where the most affected states are Bahia and Rio Grande do Sul. Fig. (**2**) shows a map of Brazil with the municipalities that have enacted emergency due to drought in 2014.

Fig. (2). Brazilian municipalities with dry critical events in 2014 [5].

The river system also suffers variations throughout the year due to rainfall [5]. So that, it is necessary to create water reservoirs able to supply the demand during dry periods. Also, the water supply often becomes impaired because of the climate change and extreme events. The year 2014 was characterized by both: excess and lack of rainfall. The southeast region suffered due to shortage, while the south and part of the north and Midwest regions suffered due to high rainfall. Fig. (**3**) shows the extreme events that happened in the country in 2014 and their return periods [5].

CHAPTER 2

Rainwater Tanks to Save Water in Buildings: An Australian Perspective

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Abstract: Water supply is an essential service to buildings along with other services such as electricity supply and telephone. Many of the new cities in developing countries do not have 24-hour safe drinking water in their buildings, and water supply is often intermittent and is of poor quality. In contrast, developed countries use a much higher volume of potable water in their buildings, which can be reduced significantly. In urban areas, sustainability and water efficiency of buildings are of great significance as many water authorities have been struggling to meet the increasing water demand due to higher populations. The climate change is bringing more extremity in the climate systems such as long and frequent droughts and higher temperature episodes, which increase water demand significantly when water availability is the lowest. This chapter presents water recycling and reuse in buildings with a special focus on rainwater harvesting systems in Australia to reduce potable water demand within buildings. It has been found that rainwater harvesting is one of the most popular means of alternative water supplies in buildings; however, there are further scopes of development in the rainwater harvesting systems by bringing innovations into these systems to make future buildings more water-efficient.

Keywords: Green building, Greywater, Mains water, Rainwater tank, Rain water, Water supply, Water recycling, Water efficiency, Waste water, Storm water, Water conservation.

INTRODUCTION

A building needs a variety of services such as electricity, water, telephone, sewerage system and air-conditioning. Among these services, water supply is of special significance as its presence is a prerequisite to few other essential services such as sewage disposal system. In many developing countries, buildings do not

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Enedir Ghisi (Ed.)

have continuous water supply *e.g.* water is supplied in morning in a day or once or twice per week. For example, in a megacity like Dhaka (the capital of Bangladesh with population over 16 million), although drinking water supply coverage was 87% in 2015, only 32% of the urban population lived in households that had piped water supply [1]. In 2011, rainwater harvesting for new houses was made mandatory towards solving water scarcity and flooding problems in Dhaka city [2]; however, it has not solved the water supply problem of Dhaka. The water supply in Dhaka is regarded as unsafe, and hardly anyone drinks this water without boiling. This is a typical problem to many large cities in the developing countries.

Presence of safe drinking water can be taken as the sign of 'balanced development' *i.e.* its absence in buildings can be regarded as lack of development. In fact, one can make a flushing building with sophisticated communication systems, but to provide clean drinking water and sewage disposal system is far more challenging as it needs much bigger investment and constant maintenance and monitoring. In a large city like Sydney, the approval of any new residential area is highly dependent on adequate water supply, which is not guaranteed. Even in peri-urban Sydney, many people depend on roof harvested rainwater to meet all their water demands as they are not connected to city's water mains.

Reduction of potable water demand in a building is highly sought in both developed and developing countries as cities are ever expanding with time, which increases water demand to a challenging level. Also, during drought conditions, water supply is stressed and authorities seek measures to reduce water demands *e.g.* application of mandatory water use restrictions. For the last twenty years or so, provision of alternative water supplies is well discussed and debated covering wastewater recycling, rainwater harvesting and greywater reuse among other sources. This chapter focuses how water demand in buildings can be supplemented by rainwater harvesting with a special focus to Australian condition.

WATER USE AND RECYCLING IN BUILDINGS

The use of potable water in buildings can be minimized significantly by pursuing two different water reuse techniques, namely rainwater harvesting and greywater reuse systems. These techniques can be adopted either separately or in a combination, especially for purposes that do not require potable water such as flushing toilets and gardening. The rainwater harvesting system mainly requires two elements - a collecting surface (usually a roof) and a water storage tank (above or below ground). In a rainwater harvesting system, possible water contamination may occur during the precipitation if the air itself is polluted (*e.g.*

acid rain) or if the collection surface contains accumulated pollutants during dry weather period. A first flush device is generally fitted with the rainwater harvesting system, which diverts first part of the runoff containing high level of pollution. In the greywater system, water is collected from less contaminated sources within a building such as bathing and washing. This water usually does not come into contact with high levels of contamination, such as sewage, and thus this water has the potential for reuse or recycling in a building. Hence, due to the low level of contamination, the harvested rainwater and greywater may be treated on-site with a simple treatment system, and has the potential to be used as potable water, which can ultimately reduce the water demand.

Australia has the second largest domestic water use rate with about 500 l/p/d (liter/person/day), followed by Italy (400 l/p/d) and Japan (380 l/p/d), while the USA has the highest water consumption rate (above 500 l/p/d) [3]. A large part of this water consumption is attributed to water use in buildings that consists of direct consumption by human beings, and water usage for various household purposes such as cooking, bathing, toilet flushing, cloth washing, general cleaning inside the households, car and hard surface washing, plant watering, filling swimming pools and recreational fountains and feeding pets/livestock.

Household sector is the second highest water user in Australia after agriculture sector [4]. Interestingly, only a small portion of residential water use belongs to potable needs. For example, potable use comprises only 9% of indoor water usage as reported in a Western Australian study [5]. It has been reported that the remaining 91% non-potable domestic water demand can be met by alternative water sources [6]. An important demographic study by Hurlimann [7] on domestic water use and satisfaction level with alternative water sources in Victoria, Australia revealed that garden watering had the highest usage among all the building water uses. Water from laundry has the potential to meet about 30% of garden water demand.

Table **1** represents water use for 2001 in twenty two largest cities in Australia. This table shows that 59% of total water use belongs to domestic water use - both inside and outside of a household. The end use of recycled water was found to be limited to landscape irrigation, car washing and toilet flushing. In Hong Kong, sea water is used for flushing about 70% of its toilets [8]. Saudi Arabia is an arid country where temperature is quite high, and there is no large river system and lake; in order to cope with the increasing water demand the Saudi Government has developed 33 desalination plants, and has emerged as the largest producer of desalinated water in the world [9]. Studies on application of sustainable architectural principles for developing water efficient residential buildings in Saudi Arabia have resulted in few modifications to traditional building design to

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CHAPTER 3

Criteria for the Optimal Sizing of Rainwater Harvesting Systems in Europe

Ilaria Gnecco[1,*], **Anna Palla**[1], **Alberto Campisano**[2] and **Carlo Modica**[2]

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Abstract: Rainwater Harvesting (RWH) systems are recognized as a widely accepted solution to save potable water in buildings. In addition, RWH systems may play an important role in mitigating the impact of increasing imperviousness in urban areas by contributing to increase both at-source retention and detention of storm water runoff. The chapter provides an overview of methodologies for designing RWH systems, with specific focus on numerical models based on the long-term water balance simulation of the tank. An overview of metrics to evaluate RWH system performance is presented, with regard to the estimation of both water saving potential and storm water control benefits. The accuracy of the modelling results with reference to the length of the available rainfall series and to the selected resolution time step of the used model is discussed. Results of an application to six cities in southern Europe are also discussed in order to highlight the impact of different precipitation regimes as well as the influence of rainwater demands on the system design and performance. Finally, the German, British and Italian standards on RWH are analysed and compared to identify differences and common design approaches.

Keywords: Behavioural model, Detention time, European standards, Long-term simulation, Operational parameters, Precipitation, Rainwater harvesting, Rainwater demand, Runoff control, System performance, Tank sizing, Water saving, yield.

INTRODUCTION

Rainwater Harvesting (RWH) systems are recognized as a widely accepted solution to save water in buildings. RWH has gained increasing popularity and confidence in Europe due to the improved reliability of system design and implementation issues. The installation of rainwater harvesting systems, as well as

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Enedir Ghisi (Ed.)

the use of water saving devices, are supported by the European legislation [1]. A significant number of studies from the literature (*e.g.* [2 - 5]) confirms the potential of RWH as an alternative source of fresh water in the house.

Domestic RWH consists of the small-scale concentration, collection, storage and use of rainwater coming from rooftops and other impervious surfaces. Rainwater can be used to replace drinking water for many uses in the house such as the flushing of toilets and the garden watering [6]. Several studies carried out across the world over the years have focused on RWH for toilet flushing. In many cases, this use represents one of the largest components of the household water consumption without requiring necessarily high water quality requisites [7, 8].

RWH systems may also play an important role in mitigating the impact of urban storm water due to the increase of imperviousness in urban areas [9]: according to the Low Impact Development (LID) principles and applications aimed at promoting storage, infiltration and evapotranspiration [10], RWH may contribute to increase at-source retention and detention of storm water. Then, catchment scale implementation of rainwater tanks may help to reduce frequency, volume and peaks of storm water runoff in urban drainage systems [11 - 14]. Moreover, the synergy between different LID systems can contribute to maximize the benefits and provide a range of urban ecosystem services (including mitigation of floods, droughts, noise, air pollution and urban heat island effects, improvement of biodiversity, *etc.*) [15].

Within this framework, the main objective of this chapter is to provide an overview of common methodologies for designing RWH systems and assessing their performance. A specific section is devoted to the analysis of the impact of the European precipitation regimes on the management of rainwater tanks as well as on the influence of water demands on the system performance. Further, design criteria are compared with standards provided by the main guidelines available in Europe, such as the British, the German and the Italian technical recommendations.

OPERATIONAL AND DESIGN PARAMETERS

RWH systems are usually made of three main components namely, the catchment area, the storage system, and the conveyance system. Devices used in the various system components are filters, one or more storage tanks, a supply facility, a separate pipe network and an overflow unit. Each component can be described in a simple way in terms of operational parameters. In the following sub-sections, the design parameters of the RWH systems are illustrated in detail.

Operational Parameters

Catchment Area

Any RWH system is designed in order to collect rainfall precipitated over a specific catchment area. The amount and quality of collected rainwater depend on the area and type of the catchment. The main operational parameters describing the catchment consist of its surface area and typology. The catchment area is generally impervious in order to maximize the runoff volume. Collection areas are usually rooftop surfaces or other paved areas (*e.g.* parking lots, small road networks). In the latter case, the impact of the associated pollutant load may be significant [16] thus requiring at least to divert the first flush volume from the total collected rainwater. The diverted rainwater volume can be evaluated based on results provided by the literature. As examples, Khastagir and Jayasuriya [3] subtract the first 0.33 mm of daily rainfall while Basinger *et al.* [17] assume 0.4 mm to be the first flush occurring after 3 dry days. Other authors recommend first flush amounts up to 200 litres per 100 m^2 of rooftop (2 mm) [18].

In the most basic and common solutions, rooftop rainwater is conveyed to the storage unit through the system of gutters of the building. Conversely, the conveyance of storm water runoff from other paved areas requires a dedicated drainage network. As for rooftops, the amount of collected rainwater is usually evaluated by assuming a constant runoff coefficient as a measure of losses in the surface depression storage. Based on this simplification, the volume of rainwater is calculated by multiplying the surface area by the runoff coefficient and the rainfall depth. The runoff coefficient is generally assumed in the range 0.8-0.9, which are typical values for rooftops of residential districts.

Storage System

Tanks for harvesting rainwater may be either above or below ground reservoirs. Various types of rainwater storage facilities can be found in the practice: cylindrical tanks and battery tanks (*i.e.* interconnected tanks) made of pottery, cement or polyethylene materials. Precautions required to use storage tanks include provision of adequate devices to minimise contamination from human, animal or other environmental pollutants including a tight cover to prevent algal growth and the breeding of mosquitos. Open containers are not generally recommended to store rainwater for domestic use. Since the tanks are generally covered, evaporation losses from the RWH system as well as the incident precipitation over the tank can be neglected in the water budget estimation.

The main operational parameter of the storage device is the storage capacity of the system, *i.e.* the maximum tank water volume that can be supplied to the final use.

CHAPTER 4

Economic, Environmental, and Social Criteria Evaluation of Rainwater Harvesting System Options for an Office and Lab Building on the University of Utah Campus

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Abstract: This chapter presents an approach for using multi-criteria decision analysis (MCDA) to study the tradeoffs of rainwater harvesting (RWH) system designs. Three scenarios have been designed and evaluated. Each one captures rainwater from the rooftops of the connected Civil and Materials Engineering (CME) and Hedco buildings on the University of Utah campus. Scenario 1 utilizes two separate storage cisterns; one large underground, and one smaller placed on the top of the CME building. Scenario 2 utilizes only one large underground cistern. It uses a pressure-regulated pump to supply a constant flow of water to each toilet in the building. Scenario 3 utilizes only one large cistern placed on top of the CME building. The design includes a pump to convey collected runoff from the Hedco building to the rooftop cistern. From there, toilets are flushed from the gravity-fed water. MCDA was used to integrate environmental impacts, cost, water use and social impacts of the proposed scenarios. GaBi software was used for environmental impact analysis; TRACI and ReCiPe were used as assessment tools. After assessment of the designs, it is suggested that Scenario 3 represents the most favorable option for any change to the toilet-flushing system in the CME.

Keywords: Concrete cistern, Environmental impacts, Economics, Fiberglass, GaBi, Global Warming Potential, Irrigation, Multi-criteria, Rainwater harvesting, Social impacts, Toilet flush.

INTRODUCTION

According to Utah foundation report in 2014, Utah's population has increased almost three times since 1970, and is estimated to be doubled by 2050 [1]. As

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Enedir Ghisi (Ed.)

population grows, water demand also increases, and the cities with inadequate water supplies can experience the negative effects of water scarcity. Rainwater harvesting (RWH) offers a possible solution to this problem by capturing rainwater runoff from impervious surfaces (mainly rooftops) and storing it for later use. RWH has been practiced for centuries but was abandoned as cities developed extensive water distribution systems. Yet, as of the past decade, a renaissance of RWH has occurred with many studies from many parts of the world (*e.g.* Africa [2]; Asia [3 - 5], Australia [6], Europe [7, 8], North America [9 - 11]).

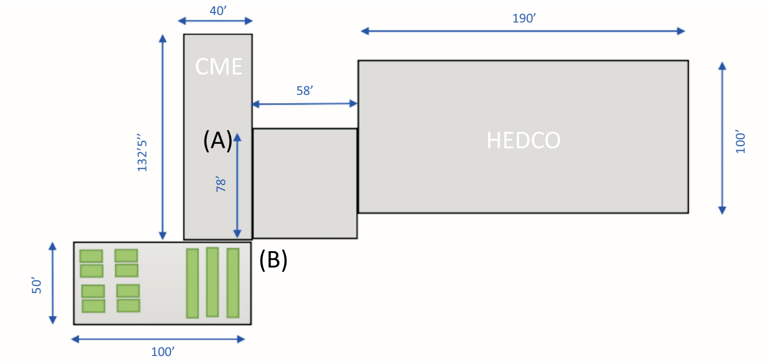
RWH systems have typically been assessed in the literature according to their energy consumption, water saving potential, and greenhouse gas emissions [12 - 16]. Some detailed life-cycle environmental impact assessment reports that discuss acidification, eutrophication, toxicity, ozone depletion, fossil depletion *etc.* impacts of the RWH systems, have also been published recently [17 - 20]. However, in addition to technical and environmental evaluations, economic and social indicators should be incorporated in evaluations of RWH systems as part of sustainable design.

Sustainable design of buildings to include RWH systems can be addressed *via* a multi-criteria decision analysis (MCDA). MCDA has been used to analyze a variety of problems; remediation [21], energy solutions [22], environmental policy [23] or integrated risk assessment [24]. This study presents an approach for using MCDA to integrate environmental impact, water use, life cycle cost and social impact from three proposed RWH scenarios that can be implemented in an educational building on the University of Utah campus (the Civil and Materials Engineering (CME) building and the Hedco lab building, which connected by a covered walkway). The background objective of this study was to establish analytical basis to evaluate high performance RWH systems that would enable designers to base choices on comprehensive evaluation.

METHODS

Site Description

The focus for this study consists of two connected buildings, the CME building and Hedco, on the University of Utah campus in Salt Lake City, Utah. The CME building is 4 stories tall with extra height for mechanical equipment. Hedco is 3 stories, but approximately 30 feet lower. The building footprints are slightly offset, as shown by the plan view drawing in Fig. (**1**). The CME building contains faculty and student offices, while Hedco contains an array of laboratories and shops for machining, materials processing, and chemical analysis. The total roof area of CME and Hedco is 28,824 ft^2. There is great interest to implement water conservation and storm water management features on the University of Utah campus and this building provides a potential location for RWH.



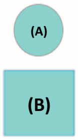
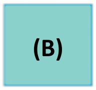
Scenario	**1**	**2**	**3**
Tank/Location			
Material	Fiberglass Tank A, Concrete Tank B,	Concrete Tank B,	Fiberglass Tank A
Capture area	CME for Tank A , CME and Hedco for Tank B	CME and Hedco	CME for Tank A
System aids	• Pump to feed A • Reinforcement • Water treatment • Educational Garden	• Pump to feed each toilet flushing	• Pump to redirect harvested water from Hedco to CME • Gravity fed • Reinforcement • Educational Garden

Fig. (1). System layout for three scenarios.

Scenarios

Overview of Scenarios

RWH systems are tanks/cisterns placed atop or on ground level of a site or building to collect and store rainfall or runoff. The location of the tank/cistern affects required equipment (*e.g.* pump, pipeline, *etc.*), and cost and energy usage. The work described in this paper studies three RWH configurations with different cistern storage volumes and locations (Fig. **1**). The first scenario has two storage cisterns; one large underground, and one smaller placed atop the CME building. The idea is to use both locations and see if maximizing the amount of collected rainwater can maximize the benefits of the RWH system. The roof tank is smaller

CHAPTER 5

Technology Improvements or Influencing User Behaviour for Water Savings in Administrative and University Buildings: Which One Should Come First?

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Abstract: Technology upgrades or investment in changing user behaviour? This is a common dilemma when it comes to improving water savings in administrative buildings. The answer is obvious: both, but only after a management scheme is in place. Several real scale experiments have been carried out at the Federal University of Bahia, Brazil, and in the administrative buildings of the government of the State of Bahia over the last 17 years with significant results however, less than expected. This paper discusses the role played by so-called water saving devices and that played by maintenance activities and continuous calibration. A conceptual scheme to guide water savings in buildings as well as actions that must be considered in water saving programmes are presented. The conceptual guide considers the role of following-up water consumption on a daily basis by administrators but with data open to the public. It further presents an approach to understanding the reasons for water losses and water waste and the means to reduce them in institutions with clear technical and economic limitations. Consumption monitoring and control is the most important action to be taken and this has to precede further efforts or investments such as the acquisition of water saving devices or greywater use and rainwater catchment.

Keywords: Conservation, Institutional building, Rational use, University premises, Water saving, Water end-uses, Water consumption monitoring, Water awareness, Water demand management, Water soft path.

INTRODUCTION

This chapter discusses the implementation of water saving programmes in institutional buildings focusing 17 years of experience of Teclim/UFBA, a

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research group at the Federal University of Bahia, Brazil. Besides having worked with large industrial sites, Teclim has constantly been taking part in water saving programmes in university buildings and governmental premises in Bahia. As explained in this chapter these programmes have led to a significant reduction in water waste and loss but they fall short of our expectations.

Perhaps our expectations were too high but they could not be different as we are aware of the hardship of constructing the utopia of sustainability. Moreover, we are fully aware that failure to reach minimum sustainability advances will mainly fall on the heads and shoulders of populations in developing regions. Society is failing to develop decent consumption practices especially at government and teaching institutions. Such places should lead by example and by failing to do so they jeopardize their main objectives.

We have reviewed several authors who suggest and describe programmes to rationalize water consumption in institutional buildings. As expected, their approaches have a lot in common. They all include technological and behavioural aspects that have to be brought together in a managerial context. Readers interested in putting forward organized action for saving water in an institution will find many examples in the technical literature. However, they should not expect it to be an easy task. It will require long-term persistence despite initial gains and economy. Long term durable solutions will require the building of a permanent awareness. That is, an institutional attitude capable of resisting the ever-changing characteristics of these organizations: A natural resources respecting culture.

Towards this we discuss the factors that define consumption patterns in these kinds of buildings and organize them in a conceptual model. The reader might agree that an effective way to promote savings of any resource is by charging for its use. This is very difficult to do in the type of edifications we are studying here and other mechanisms have to be used. Among these, we highlight the need for an Eco-team, an internal group responsible for conducting the water saving programme and implementing daily monitoring and control.

Furthermore, this work presents some basic tools to be included in a programme to promote the rational use of water in government administrative and university buildings which may also be useful for other types of premises for public use. These tools were used in the programmes developed with Teclim's participation, the results of which are described at the end of this chapter, just before our conclusion.

One word of warning however, although general action lines are useful to develop a water rationalization programme, each case is a particular case with its own wealth of details and, as the saying goes, "the devil is in the detail".

RATIONAL CONSUMPTION OF WATER IN THE CONTEXT OF THE ENVIRONMENTAL CRISIS

> *The problem with the concept of sustainability is that everyone seems to understand what is meant by it in its promiscuous usage, however, everybody understands it differently from all others* [1].
>
> *The world's current energy prospects are – put simply – unsustainable* [2].

Trivialization of the concept of sustainability [1, 3] makes it more difficult to implement the solutions for several aspects of the environmental crisis we are undergoing. Climate change, its most publicized face, have already shown that solutions will have to be very radical [4], much more radical than those acceptable to most authorities, voters and in particular, consumers. Market forces take advantage of this scenario by offering more goods to buy, aggravating the problem in two ways: Increasing consumption and forging the idea that we are the environmental heroes our kids expect us to be, just because we are now consuming "green" gadgets.

Climate change, however, is just one of the environmental sectors where the planetary boundaries have already been dangerously exceeded. The work of Rockström *et al.*, featured in Nature in September 2009, just before COP 15 [5] and Steffen *et al*. [6], allowed a broad discussion of nine, much interlaced sectors that must be considered when designing paths to deal with these environmental problems. The limits of three or four of these have already been dangerously surpassed and surprisingly water availability is not among them!

Imagine trying to explain that to people living in water stressed regions. If in California, Israel or Dubai we will get a clear, rapid, answer. Put more money into it! Put in more technology and the problem will be solved. However, if in arid or semi-arid poor or developing regions, response will be quite different.

This short discussion brings us into a more profound debate, as the one raised by Jaramillo and Destouni [7] and answered by Gerten *et al.* [8]. Global boundaries should not stop us from discussing local problems. This is even more so when solutions to environmental problems in one sector enlarge problems in other sectors.

CHAPTER 6

Water Savings in Rainwater Harvesting Systems in Portugal: Influence of Weather and Type of Building

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Abstract: Nowadays, water management is necessary to optimize the use of this key resource. As such, increasing water efficiency through the reduction of consumption and/or resorting to alternative water sources is a challenge of the near future. Rainwater harvesting is an accessible alternative source of water for non-potable and potable uses in many parts of the globe. Rainwater can be collected easily and, in many cases, its use may not require significant treatment, even for potable purposes. Yet, rainwater harvesting (RWH) systems are still not common in most of the water supply projects, namely in Mediterranean countries such as Portugal. The promotion of RWH systems involves viability analyses estimating the expected water savings for different climate and water consumption patterns. This chapter evaluates the performance of rainwater harvesting systems of several case studies in Portugal, covering different water use patterns and geographical locations. The water consumption pattern, both in time and end-use, influences the potential for rainwater use. Water consumption was monitored in residential buildings (a single family house and a building), a shopping centre and a university building. Simulations are presented for different locations in Portugal, in order to assess the influence of weather in the efficiency of RWH systems. In addition to the rainfall amount, its distribution in time and space also contributes for the rainwater availability. The operational data from an existing rainwater harvesting system is used to calibrate the model and evaluate its sensitivity to the main parameters. Tank optimization for each case study is discussed. The Mediterranean climate, characterized by distinct wet and dry seasons and significant variability of the rainfall events intensity and duration, shows substantial variation of the inter-annual water savings from a rainwater harvesting systems. The results show that rainwater harvesting systems in Portugal are a relevant alternative water source in different types of building.

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Keywords: Commercial buildings, Portugal, Rainwater harvesting, Rainfall regime, Residential buildings, Simulation, University buildings, Validation, Water consumption pattern, Water savings.

INTRODUCTION

The XX century was characterized by population growth [1], water consumption increase and water sources pollution [2]. As a result, water became a key resource at risk. In 2000 its relevance was recognized internationally by the United Nations when defining the UN Millennium Development Goal of reducing by half the proportion of people without sustainable access to safe drinking water until 2015 [3]. Although 2.6 billion people have gained access to improved water sanitation since 1990, in 2015 the goal was far from being fulfilled in some parts of the globe [4] and universal access to clean water and sanitation became one of the 17 Global Goals on the 2030 Agenda for Sustainable Development [5].

Several parts of the globe are already facing problems related to water scarcity or will face them in a near future, most notably in Africa, with over 40 percent of the world's population affected in 2015. Projections point to an increased global water stress and scarcity in the future as a result of the forecasted climate change, with estimates that water related challenges will affect two thirds of the world's population by 2025 [2, 5 - 7]. This is more critical in developing countries, particularly in poor rural areas, where at least one-third of the population has little or no access to safe drinking water. As a consequence, major health problems from waterborne diseases add to the complex problem of stress and scarcity [4, 8]. In Europe, generally, the risks of water stress, and specially water scarcity, are smaller. However, public water supply systems imply a significant consumption of various other resources (*e.g.*, building, maintaining, operating and rehabilitating/replacing the supporting infrastructures [9, 10]) and represent a significant burden both at an economic and environmental levels. Considering the water-energy nexus alone will motivate the evaluation of alternatives for a more efficient water use, even in wealthy developed countries with water resources available higher than the water demand.

Improved water management is crucial in less developed countries, since several tend to locate in regions of the globe with higher water scarcity and stress and there are less resources and infrastructure available. In the more developed countries, water efficiency promotion by organizations with responsibilities in the water sector has been driven by sustainability. Resource optimization through the combined implementation of structural (*e.g.*, reduction of water losses) and non-structural (*e.g.*, education campaigns) measures [13] have proven to benefit the economy, environment and society [11, 12]. As a results, some countries where able to stabilize or even decrease the water use in various sectors (*e.g.*, residential; industry; agriculture) during the last decades.

Water management optimization solutions in buildings can be categorized into two main groups based on the underlying goal: i) water consumption reduction; and ii) alternative water sources use. The former includes promoting conscientious water consumption habits and lower water consumption devices development and implementation for a more efficient water use. Education campaigns, water tariffs varying with water consumption, low discharge fixtures and appliances are amongst the solutions to decrease water consumption. The latter involves the exploitation of alternative water sources to either replace or complement the public water supply. These alternative water sources include salt water, groundwater, greywater and rainwater.

The use of rainwater for both potable and non-potable applications is not a novelty, and people has resort to it for thousands of years throughout the world [14]. Nowadays, RWH in buildings is being used for different purposes depending on the country development. Coping with water shortages for potable and non-potable use [16] has been the main motivation underlying RWAH in developing countries such as Bangladesh, Botswana, China, India, Kenya, Mali, Malawi or Thailand [11, 15]. In more developed countries such as Belgium, France, Germany, Japan, New Zealand, Singapore or United States, RWH use is being promoted mainly to complement conventional systems for non-potable use, namely for toilet flushing, clothes washing, outside washes and irrigation [17 - 23], but also for potable uses (*e.g.*, Australia [24]). RWH is not limited to residential buildings and large scale systems are also found in collective housing and other types of buildings in countries such as Japan [25], the UK [26, 27], Germany [28] or Portugal [29].

Legal and/or regulation limitations and/or gaps, initial cost, social acceptance and treatment requirements have been some of the most significant obstacles to the implementation of RWH systems. In countries where water scarcity and stress is not yet a major concern, the most relevant stimuli for using RWH as an alternative water source are usually related to sustainability concerns, which include environmental issues (*e.g.*, climate changes, population growth, pollution) and the total costs of public water supply (investment, operation, maintenance and rehabilitation/replacement or disposal). This resulted in regional and/or national initiatives to promote RWH in countries such as Australia, Germany or the USA [30]. RWH has also been promoted to complement storm water management in urbanized areas (*e.g.*, Germany).

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CHAPTER 7

Health Issues and Security of Water Saving Systems

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Abstract: This chapter focuses on the health issues related to the application of Water Saving Systems (WSS) in buildings. It stars by showing the environmental and economic advantages of these systems and then presents the main obstacles to their large-scale implementation: concerns about water quality, the security of the users and the implications on the public infrastructures. For these reasons, it is important to carefully study this question, list all health issues related to the use of WSS and show how they can be minimized and avoided. The base for this chapter is several feasibility studies, made in different types of buildings, and population surveys showing concerns about the user's security. Studies about water quality in existing WSS are also presented, as well as important security measures presented in international legislation and standards. The conclusions allow us to understand if this question is being properly discussed (if all the main problems are being covered), which measures are being applied and if others are needed.

Keywords: water efficiency, rainwater, greywater, advantages, obstacles, public perception, health issues, contamination, security, maintenance.

INTRODUCTION

Water Saving Systems (WSS)

Currently used in an unsustainably way, not only because of the exponential growth of the population on the planet, but mainly due to the global model of

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economic growth that over-consumes the resources, fresh water is becoming a limited resource. As climate change will worsen the situation in many areas of the planet, the adoption of sustainable practices in water use has become urgent and indispensable.

The first step to sustainability is the efficiency. In buildings, the best way to achieve an efficient use of water can be summarized as a principle which is known as "the 5R principle" (Fig. **1**) [1].

•Reduce consumption
•Reduce losses and waste
•Reuse water
•Recycle water
•Resort to alternative sources

- WATER EFFICIENCY IN BULDINGS

Fig. (1). The 5Rs principle for water efficiency in buildings.

The first R (reduce consumption) includes the adoption of efficient products, devices and procedures (such as smart landscaping), without prejudice to other nontechnical aspects of economic or sociological nature. In this scope, the labelling of water efficiency of products is an essential measure to provide information to consumers.

The second R (reduce losses and waste), may involve interventions such as the monitoring of losses in buildings (flushing cisterns, watering gardens, *etc.*) or the installation of circulation and return circuits of sanitary hot water.

The "reuse" or "recycling" of water differs from a traditional use by the re-introduction of water at the start of the circuit (after treatment). There is the possibility of using treated wastewater for some purposes, such as watering gardens, and also using only greywater (wastewater from washing basins, baths or laundries) which has a recognized viability in some situations and has already several applications known in many countries [2 - 4]. In fact, domestic wastewater can be divided into black water, dark greywater and light greywater. The black water is generated in the toilet, dark greywater is generated in the dishwasher, in the kitchen sink and in the washing machine, and light greywater is produced in the washing basin and bathtub. Total greywater (dark + light) represent a significant amount of domestic wastewater and, according to some studies, contribute to an increased concentration of some pollutants and contaminants in wastewater [5], which can be harmful to public health and the environment.

Finally, the resort to alternative sources may involve the use of rainwater, groundwater and even salt water. Rainwater harvesting has a great potential to be included in urban water cycle, even in seemingly adverse climates such as the

Mediterranean (where the hot summers are typically dry) and presents additional advantages, such as the reduction of the urban runoff, reducing the flood peaks in urban areas and the pollutant loads. If applied in a large scale, rainwater harvesting actually reduces a city's external water demand and relieves water stress by promoting significant potable water savings [6].

Rainwater harvesting (RWH) is a widely known and used technique in Asia, Africa, and has a great technological development in some European countries. Worldwide, regulations and incentives to foster the use of rainwater have been reported [7]. A RWH system generally consists of a catchment area (usually the roof area), a filter, a storage tank, a supply network, pipes and an overflow unit [8]. The feasibility of these systems depends greatly on rainfall magnitude and intensity. In regions characterized by low precipitation rates, rainwater harvesting alone is not enough to meet the water supply demands of rural and urban population [9].

On the other hand, the interest in greywater reuse (GWR) is rapidly growing in cities located in arid and semiarid zones of growing economies because of fresh water scarcity, the increasing water demand associated with the increase of population, and rapid industrialization. In these regions, greywater reuse may contribute to alleviate water shortage and stress on existing water sources, exacerbated by the climate change. Greywater treatment and reuse is an alternative to provide non-potable water to households and reduce water usage per person by up to 50%, or even more [7, 10 - 12].

All these measures can be easily considered in new buildings or even in refurbishment projects. For existing buildings, water efficiency audits are the appropriate procedure to find the best options, in the technical-economic point of view, to improve the efficiency.

Environmental and Economic Advantages of WSS

The various measures described for an efficient use of water, summarized by "the 5R principle", may be addressed by its environmental and economic advantages point of view. In fact, the environmental advantages are strictly connected with the economical ones: a reduction of potable water consumption leads to significant reduction on water bills and the reduction on hot water consumptions (by introducing efficient showers, for example) leads also to a reduction on the energy spend in the heating process.

Dwellings generally have a high concentration of energy demand and consequently are responsible for a high amount of greenhouse gas (GHG) emissions, including CO_2, which induces important environmental impacts.

SUBJECT INDEX

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