Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 89 (2014) 1515 – 1521
Procedia Engineering
www.elsevier.com/locate/procedia

16th Conference on Water Distribution System Analysis, WDSA 2014

Rainwater Management in Compliance With Sustainable Design of Buildings

M. Zeleňáková[a,*], G. Markovič[b], D. Kaposztásová[b], Z. Vranayová[b]

[a]*Technical University in Kosice, Faculty of Civil Engineering, Dept. of Environmental Engineering, Vysokoškolská 4, 04200, Kosice, Slovakia*
[b]*Technical University in Kosice, Faculty of Civil Engineering, Dept. of Building Services, Vysokoškolská 4, 042 00, Kosice, Slovakia*

Abstract

Continuous growth of population and consequent growing need for drinking water is a global problem. Effective use of rainwater for for toilet flushing, laundry, gardening or washing thus saving about 50% of drink water. Overall, urban drainage presents a classic set of modern environmental challenges: the need for cost-effective and socially acceptable technical improvements in existing systems, the need for assessment of the impact of those systems, and the need to search for sustainable solutions. The paper describes comprehensive rainwater management approaches and contains an overview of the source control techniques as well as practical examples of rainwater use for non-potable purposes.

Peer-review under responsibility of the Organizing Committee of WDSA 2014
Keywords: Rainwater management; rainwater harvesting; sustainable urban drainage.

1. Introduction

There are numerous techniques and approaches known around the world how to support sustainable rainwater management, especially in the urban areas, where the storm water can cause significant damages. The aim is to manage rainwater as close to source as possible which is also called source control covering number of measures. Rainwater harvesting as a part of the source control measures could contribute to the sustainability in rainwater management as well, by supporting potable water conservation and sustainability in water management in general. There are at least two very important facts, which need to be considered when dealing with the rainwater management. It is increasingly

* Corresponding author.
E-mail address: martina.zelenakova@tuke.sk

Peer-review under responsibility of the Organizing Committee of WDSA 2014
doi:10.1016/j.proeng.2014.11.442

changing climate, resulting in short term but more intensive precipitation in one hand and increasing droughts in some countries in the other. The second fact is increasing urbanization over the last years, which has changed the natural water processes and increased the urban runoff significantly. These facts have influenced urban drainage and it is assumed that they will influence it even more in the future.

2. Rainwater – alternative water supply source for buildings

Effective use of rainwater from capturing rainwater for further reuse represents one of alternatives of saving so precious drinking water. Every building has potential to be used for capturing rainwater. Surface area or surface for capturing rainwater is determined by roof structure or other compact surface from which rainwater is drained by drainpipes into storage reservoir. The most common type of building used for capturing rainwater is family house. Theoretical yearly profit of rainwater depends on precipitation and roof area for rainwater capturing – Fig. 1. Rainwater is in our conditions - Slovakia used only as service water.

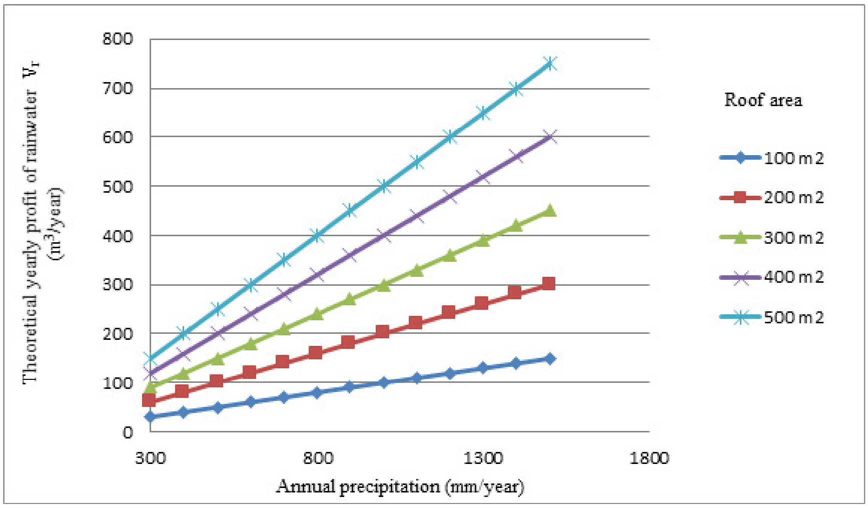

Fig. 1. Theoretical yearly profit of rainwater

Rainwater can be used as follows:

- flushing the toilet
- irrigation
- washing
- doing the laundry
- in some countries rainwater is considered to be used also as drinking water after necessary purification

The use of drinking water for flushing toilet represents 1/3 of overall average water consumption. This fact gives credit to reuse of rainwater mostly from the environmental point of view. Among other, reuse of rainwater minimizes the flow of rainwater to wastewater disposal system. Even though rooftop surface represents only a fragment of all urban surface area, drainage of rainwater from rooftops into storage reservoirs minimizes the flow of rainwater to waste-water disposal system and has positive impact on sewerage system.[2] [3].

2.1. Rainwater storage reservoir and their planning conception

Storage reservoir represents main component of whole system of rainwater reuse. There are many methods how to accumulate rainwater. In the past, concrete reservoirs with capacity of 2 or 3 m^3 were used. In some cases these reservoirs were made of concrete bow members. Nowadays industrial production of storage reservoirs made of plastic materials started [1].

Regarding to the planning conception there are many possibilities where to place rainwater storage reservoir taking in consideration the area of residential lot, building disposition and other.

In general, there are three basic locations for rainwater tank:

- Underground storage reservoir
- Storage reservoir as a part of basement disposition
- Over ground rainwater storage reservoir

To place storage reservoir underground is considered the best solution (Fig. 2). Sunlight cannot reach storage reservoir and therefore there are no microbiological processes having negative impact on sensory properties of water. Another advantage of underground placement is cool and stable water temperature. Animals and insect have almost no access to the storage reservoir. Area requirements do not represent a problem with placing of water reservoir. Possibility of flooding out the building is also eliminated. Capacity of underground storage reservoir is not limited.

Fig. 2. Underground rainwater tank, over ground rainwater storage reservoir, and storage reservoir as a part of basement disposition [5, 6]

In comparison with underground storage reservoir, placing of storage reservoir as a part of basement disposition represents easier solution (Fig. 2). There is no need of excavation work for storage reservoir and piping system. Service and maintenance of such a storage reservoir is also easier due to simple and easy access. Possibility of flooding out basement area or area requirements can be considered as disadvantage of this solution. Storage reservoir can be placed as a direct part of basement disposition or in a separate room. Capacity or storage reservoir is limited by basement disposition area.

Over ground rainwater storage reservoir is mostly placed in proximity of the building from which the rainwater is captured (Fig. 2). Easy service, access, monitoring and maintenance are advantages of this type of storage reservoir. Area requirements given by capacity of reservoir represent disadvantage. Animals and insect can access the reservoir, which is at last but not least also under the influence of sunlight and air temperature.

3. Research in the real condition

This paper is devoted to the analysis of the possible use of rainwater in the real building, exactly in the campus of Technical University in Kosice. The task of the research was to prove efficiency of using the rainwater for flushing the toilets in an exact building in the campus. It is necessary to have a sufficient volume of rainwater to have the possibility to use it for flushing. It depends on the intensity of rainfall and the area of the roof of the building from which the rainwater is drained (Fig. 3).

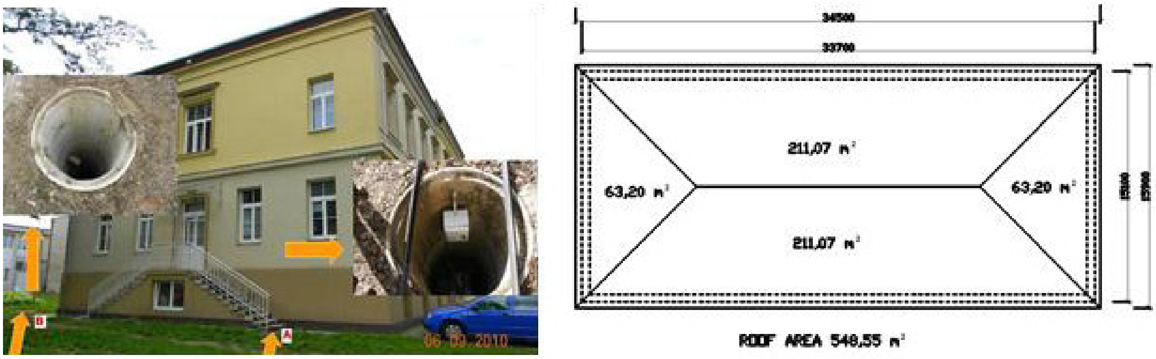

Fig. 3. Location of infiltration shafts near building PK6 and ground plan of PK6 roof [4].

3.1. Measuring devices

The devices that provide us information about the quantity of rainwater are located in the campus of Technical University of Kosice. The rain gauge (Fig. 4) is located on the roof of University Library. The amount of rainwater drained from the roof of building PK6 is measured by ultrasonic level sensor placed in measurement flume (Fig. 4) in the shaft near the building PK6. Roof area of the PK6 building is 548.55 m^2.

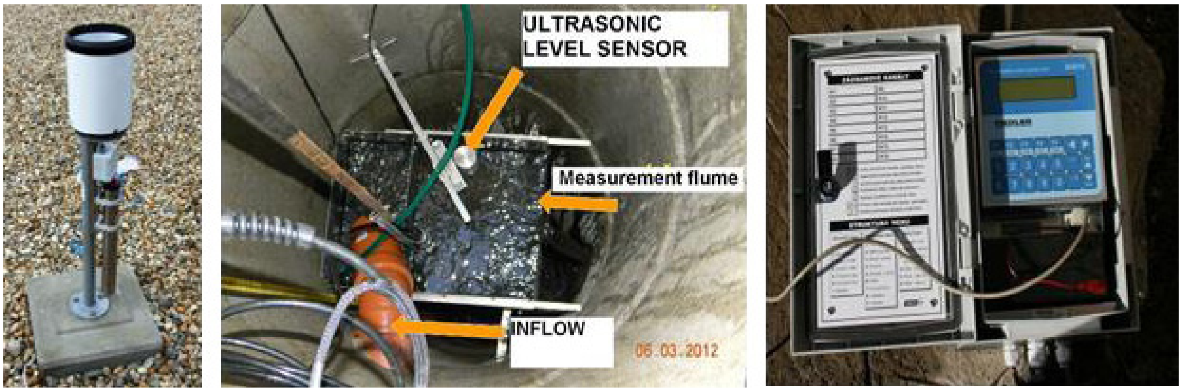

Fig. 4. Rain gauge on the roof of University Library, measurement flume with ultrasonic level sensor and data unit M4016 in shaft A [4].

All rainwater runoff from roof of this building is flow into the two infiltration shafts. Both infiltration shafts are located at the east side of the building PK6. The shafts are realized from concrete rings with the outer diameter of 1000 mm. The measuring devices that provide us information about volume of incoming rainwater from the roof of the building PK6 and information about the quality of rainwater are located in these infiltration shafts [4].

Headquarters, respectively a control/data unit for generating of measurement data, is a universal data unit M4016, which is situated in the infiltration shaft A (Fig. 4). Infiltration shaft B, respectively devices located in this shaft, are also connected to the control unit. Registration and control unit equipped unit M4016 includes universal data logger, telemetric station with build-in GSM module, programmable control automat and multiple flow meter if M4016 is connected to an ultrasonic or pressure level sensor [7]. The unit M4016, in which the signal transmitted from the ultrasonic level sensor is preset up to 14 equations or the most used sharp crested weirs. Flow rate calculation from relationship water level/flow rate. For the purposes of our measurements is to calculate the instantaneous and cumulative flow, calculated from water level used by predefined profile - Thomson weir.

3.2. Possible use of harvested rainwater in real conditions at the university campus of Kosice

Totals of rainfall represent the theoretical amount of rainfall in mm, falling on the surface of interest. Totals of rainfall depend on specific locations. The average of yearly totals of rainfall is about 770 mm/year in Slovakia [8].

In general, the rainwater harvesting system depends on:

- Required volume of water
- The amount of precipitation
- The size of roof or another catchment surfaces

As already mentioned above, the research is done in the area of Kosice - at the campus of Technical University of Kosice. Fig. 5 represents annual precipitation for the Kosice-city in the years 1900-2010 and theoretical yearly profit of rainwater from the building PK6 with roof area 548 m^2 according to yearly precipitation from the years 1900-2010 for the city of Kosice [9]. Average value of annual precipitation is 628 mm/year.

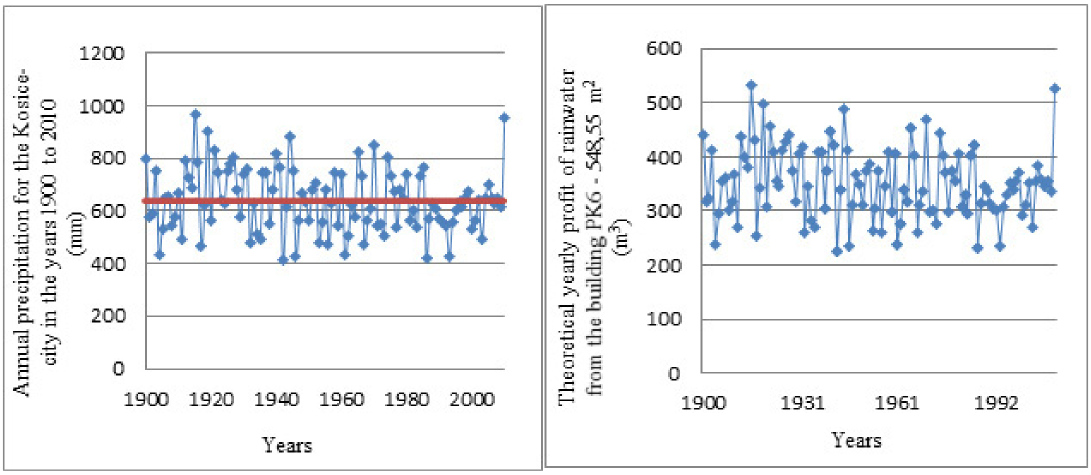

Fig. 5. Annual precipitation for the Kosice in the years 1900 to 2010 and theoretical yearly profit of rainwater from the building PK6 [5]

Intensity of rainfall in combination with rooftop area or another paved surface will determine maximum volume of rainwater possible to capture and accumulate. Initial measurements start and continue in infiltration shaft A since March 2011, when began measurements of the inflow of rainwater runoff from the part of roof (212 m2) of the building PK6. Table 1 represents the measured volumes of rainwater from the roof area of 212 m2 of PK6 building for possible use in this building. In March 2012, the research was extended of measurements of rainwater quantity in infiltration shaft B. It provides us data of rainwater quantity from all roof area (548.55m2) of PK6 building. Table 2 represents the measured volumes of rainwater from the all roof area of 548 m2 of PK6 building for possible use in this building. (Notice: august 2012 without data due to equipment failure).

Conclusion

Reuse of rainwater for buildings in the Slovak Republic is only a little as common as in the USA, Western Europe, Australia etc.. Lower prices of drinking water and higher initial investment into technological equipment for reuse of rainwater cause this phenomenon [10], [11], [12]. This article contributes to the theme of reuse of rainwater for buildings captured from their rooftops. The aim of this article is basic planning conception of rainwater storage reservoirs and to analyze the possible use of rainwater in the real building and description of the tools what we use at the campus of TUKE for obtaining the necessary data. The main goal for rainwater harvesting system design should not be full coverage of water demand for a specific purpose in building. The main goal should be to design of these systems as an alternative source of water. This would avoid of wasting precious drinking water, which is used for example - for flushing toilets - Fig. 6.

Table 1. Volume of rainwater inflow to Shaft A – from 212 m^2 of roof [7]

Month	Volume of rainwater inflow to Shaft A – from 212 m^2 of roof (m^3)
March 2011	7.38
April 2011	1.47
May 2011	23.29
June 2011	23.45
July 2011	36.18
August 2011	6.47
September 2011	3.97
October 2011	3.23
November 2011	0
December 2011	9.75
January 2012	3.22
February 2012	0.32
March 2012	14.48

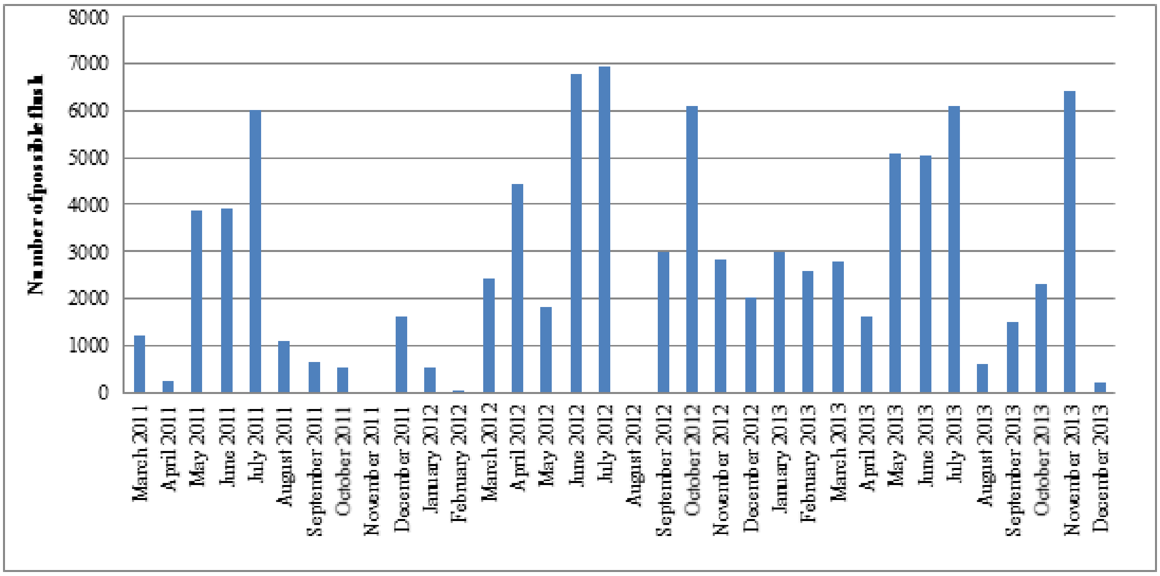

Fig. 6. Number of possible toilet flushes per month from March 2011 to December 2013 in PK6 building (1flush=6 liters)

Acknowledgements

The Centre was supported by the Slovak Research and Development Agency under the contract No. SUSPP-0007-09. The contribution is written thanks to support of project VEGA 1/0609/14.

Table 2. Volume of rainwater inflow to both shafts – from all roof area 548.55m^2 [7]

Date	Volume of rainwater inflow to both shafts A+B from all 548.55m^2 of roof (m^3)
April 2012	26.72
May 2012	10.91
June 2012	40.75
July 2012	41.56
August 2012	-
September 2012	17.93
October 2012	36.47
November 2012	16.94
December 2012	12.05
January 2013	17.92
February 2013	15.5
March 2013	16.77
April 2013	9.77
May 2013	30.55
June 2013	30.17
July 2013	36.63
August 2013	3.78
September 2013	8.94
October 2013	13.72
November 2013	38.39
December 2013	1.27

References

[1] K.H. Bose, Rainwater for house and garden (in Czech). Ostrava: HEL, 1999.
[2] V.G. Mitchell, R.G. Mein, T.A. Mcmahon, Evaluating the resource potential of stormwater and wastewater: an Australian perspective, Australian Journal of Water Resources. 2 (1997) 19–22.
[3] P.J. Coombes, G. Kuczera, J. Argue, J.D. Kalma, An evaluation of the benefits of source control measures at the regional scale. Urban Water. 4 (2002) 307-320,
[4] G. Markovič, Sustainable management of rainwater for the sewerage system buildings, Thesis, Kosice: FCE, 2012.
[5] Rainwater harvesting. WPL. Available at: http://www.buildingtalk.com/Journals//2012/08/06/WPL%20Rainwater%20Harvesting%20Brochure(1).pdf
[6] Rainwater harvesting. Gulf Coast Renewable Resources. Available at: http://gulfcoastrenewableresources.com/rainwater.html#rainwater-extra-info
[7] G. Markovič, D. Kaposztásová, Z. Vranayová, The analysis of the possible use of harvested rainwater in real conditions at the university campus of Kosice, Proceeding of the 2014 International Conference on Environmental Science and Geoscience (ESG '14), Venice, Italy, 2014, 82-88,
[8] M. Zeleňáková, P. Purcz, I. Gargar, H. Hlavatá, Research of Monthly Precipitation Trends in Libya and Slovakia, Proceeding of the 2014 International Conference on Environmental Science and Geoscience (ESG '14), Venice, Italy, 2014, pp. 46-50.
[9] H. Hlavatá, The analysis of changes of atmospheric precipitation in Kosice in the years 1900–2005, Bratislava, Kosice: SHMI.
[10] D. Słyś, A. Stec, M. Zeleňáková, A LCC analysis of rainwater management variants. Ecological Chemistry and Eng. 19 (2012) 359-372,
[11] H. Uhmannová, V. Ondrejka Harbuľáková, M. Zeleňáková, J. Dziopak, D. Słyś, M. Šlezingr, L. Smelík, Rainwater runoff in the landscape. Brno: CERM, 2013.
[12] D. Słyś, Potential of rainwater utilization in residential housing in Poland, Water and Environment Journal, 23 (2009) 318–325.