The analysis of the factors valid for quality of harvested rainwater from university building`s roof and roofing material simulation

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Abstract: This article describes the simulation of roofing material influence on the quality and quantity of rainfall water in the area of Kosice-City. It offers deep analysis of the factors valid for quality of harvested rainwater from university building`s roof and also the analysis of simulation of two model with ceramic roofing tile and organic coated metal roofing.

Key-Words: rainwater harvesting, rainwater harvested from surface runoff, quality of water, roofing material,

1 Introduction

We need to change the thinking of the society which will be in balance with nature and magnitude of the problems arising from the advent of climate variability, environmental risks, increasing urbanization and energy saving. Problems with torrential rains and drought only confirm the need for evolving new technologies, approaches and solutions as a proposal for blue alternatives for the transition to a sustainable society. Changes in climate will have significant impact on local and regional hydrological regimes, which will in turn affect ecological, social and economic systems. Some reports [1,2,3,19] suggest that warmer temperatures will most likely intensify the hydrological cycle, leading to an increase in the precipitation intensity and number of storm events. However, climate change that produces an increase in the intensity of precipitation will increase the magnitude of the design discharge and that would most likely result in adverse effects on existing water structures. The use of water has increased and in many places water availability is falling to risks levels. Progressive management of wastewater is in Slovakia relatively new topic. Due to recurrent floods we need more efficient handling of rainfall. The objective is to dispose of the water as close as possible to its origin, to what is necessary to adopt a comprehensive legislative framework and on the basis of experiments in laboratory and real-world design methodology to derive applicable management systems [19,20,]. Massive use of waste water for non-potable purposes in buildings also promotes the conservation of natural resources, water, and thus the overall sustainability in water management.

2 Aims and Methods

In the past, rainwater harvested from surface runoff - RHSR in Slovakia was used mainly for irrigation of gardens. These days, systems for collecting RHSR are built mainly in buildings like supermarkets, stadiums, etc. where RHSR is used for toilets flushing. Only negligible numbers of Slovak families use RHSR for household needs (washing, flushing, etc.). RHSR can become widely used in everyday life in the near future once systems for RHSR collecting are installed to houses, schools or office buildings. For RHSR use in households it is essential that collected water complies with both health and hygienic requirements and also meets quality requirements [2].

The aim of our research was to identify factors that affect the quality of rainwater, such as surrounding environment in which the system of rainwater harvested from surface runoff (RHSR) is located also impact of rain periods (rainfall periods or periods without precipitation) and roofing material on the quality of rainwater harvested from surface runoff.

Main goal of the research is to obtain information about rainwater collected from roofs of various roofing materials and, based on this information to identify roofing material which appears to be the most suitable material for the monitored area of Košice. The study was conducted in two places directly at campus of the Technical University of Košice as shown in Figure 2. Quality of water is measured in two model tanks, one located on a roof of university library, second on a real roof of PK6 Building (258 m far from the library building). Campus of the Technical University in Košice is located in the city of Košice - North and falls under the precipitation station SHMU Košice - City.

Assessment of individual quality indicators of RHSR follows the Regulation of the Slovak Republic (NV SR) No. 269/2010 Z. z., effective May 25th, 2010, laying down the requirements for achieving good water status results (Fig.1).

Fig. 1 Locations of research points at the campus of the Technical University in Košice (TUKE)

From our previous studies [3,4] we used the measured data from the rain gauge on the roof of University library (Fig. 2).

Fig. 2 rain gauge on the roof of University library [8]

Totals of rainfall represent the theoretical amount of rainfall in mm, falling on surface of interest. Totals of rainfall depend on specific locations. The average of yearly totals of rainfall is about 770 mm/year in Slovakia [12,13,14].

Data obtained from our precipitation station and precipitation stations SHMU are comparable, so we can take them as a guide, because we know that one of the main principles of stormwater management is to use the data as closest to the place of reuse [17,18] .

Drinking water quality is evaluated according to basic indicators :

• microbiological and biological indicators (coliform bacteria, thermotolerant coliform bacteria and faecal streptococci),

• physico - chemical parameters (pH, conductivity, levels of heavy metals and chemicals that could harm human health),

• sensorial characteristics (taste, odor, color) [2].

Factors affecting the quality of RHSR are:

• environment in which the system for stormwater harvesting operates (proximity of roads, traffic density, proximity of the manufacturing and construction industries, heavy industry, housing sector, agriculture),

• meteorological conditions (temperature, amount of rainfall periods and dry periods, course of fronts), SWR system (material used, its sustainability, filtration),

• human factors (proper sizing, regular maintenance, information about the operation of system as a whole and also about individual components) [3].

In the next two paragraphs we will describe our measurement location and goals.

2.1 Location 1- PK6 building

PK6 Building (Figure 3) is a computer center of the Faculty of Electrical Engineering and Informatics (FEI) at TUKE. System for monitoring of RHSR quality from PK6 Building consists of the following components:

• Roof - roof material: Ceberit – fibrecement small-area coating with smooth surface.

• Gutters – material: steel.

• Two concrete infiltration shafts with a diameter of 1000 mm.

• Monitoring devices placed in shafts (flowmeter - runoff of rainwater from the roof, water level sensor - water level in shaft, Levelogger - groundwater sensor, Barologger - atmospheric pressure, multi-parameter sensor of water quality (pH, conductivity) [9].

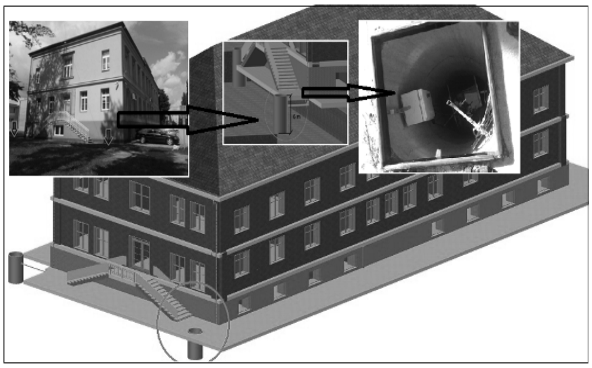

Fig. 3 PK6 Building – location of shafts

Choice of roofing material for the RHSR collecting system depends on:

- material surface structures (roughness, porosity and surface topography),
- mechanical material properties (hardness, firmness),
- resistance to climatic conditions and to environment pollution in particular region.

Combination of these factors ensures smooth operation of the system for collecting RHSR, it prolongs its lifetime and minimizes maintenance. Appropriately selected roofing material ensures adequate water quantity and quality [7,8,9] Measuring of qualitative parameters began in late 2011 using multi-parameter water sensor, type YSI 600 XL, placed in a concrete shaft. Conductivity and pH measurements took place continuously.

2.2 Location 2- university library roof - models

There are 2 equivalent models located on the roof of the University library with different roof materials (ceramic, organic coated metal roof) (Figure 4). Roofing material of the model was chosen according to the most commonly used roofing materials in Slovakia as well as for the suitability of their use for harvesting of RHSR.

Fig. 4 Location of models on the roof of university library building.

Measurement and analysis of the quality of stormwater in these models began in June 2012 on ceramic roofing material and in October 2013 on the roofing organic coated metal roof. For the analysis purposes, stormwater samples are taken from two places, i.e. from the place of „first flush" and from the 300 liter plastic tank collecting RHSR (Figure 5).

Fig.5 Samples from water tanks collecting RHSR

The analysis of the quality of rainwater is made on the spot by means of a multi-parameter water quality sensor HANNA HI 991301. Control measurements are performed in laboratory using a pH and conductivity meter WTW pH / cond 340i.

3 Results and Discussion

A. Results from experiments in PK6 building

Study in Brazil describes [5] that prolonged periods of drought provide the rain water drained roof surfaces, an increase in the values of parameters such as turbidity and color, conductivity, dissolved solids and alkalinity. Results of qualitative indicators of RHSR collected from models. The PH and conductivity was explored. Box – plot graph on Figure 6 shows pH values of RHSR collected from PK6 Building during 2013. According to Slovak legislation (NV SR) No. 269/2010 Z. z.. pH values should range from 6 to 8.5. pH values vary in particular months. Lower tolerance limit of pH 6 is exceeded during summer months from May to September.

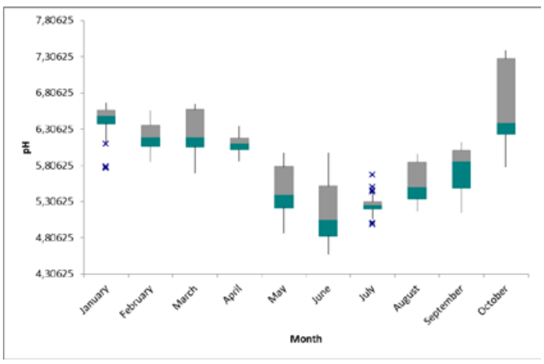

Fig. 6 pH values of rainwater from PK6 Building during 2013

Another indicator of quality of the water collected from PK6 building is conductivity. Conductivity is an approximate level of concentration of electrolytes in water. Conductivity limit for drinking water, according to (NV SR) No. 269/2010 Z. z., equals 100 mS/m which is about 1000 mg/l.

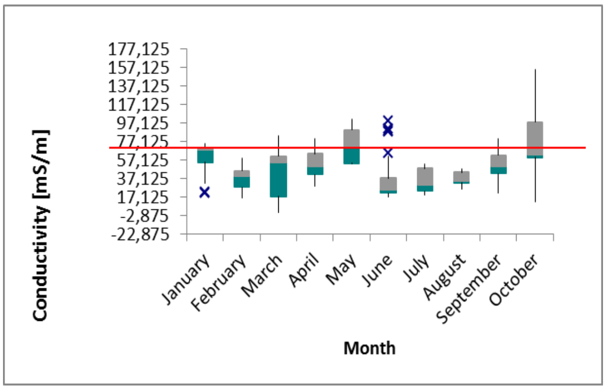

Fig.7 Conductivity values of rainwater from PK6 Building during 2013 [11]

However, optimally, drinking water should contain less soluble compounds, only about 200-400 mg/l (about 25-50 mS/m). Conductivity, similarly to pH, is measured continuously by means of a multi-parameter sensor. Conductivity values of rainwater during 2013 are displayed in box-plot graph on Figure 7. From graph below we can see that the average conductivity value for particular month varies, in most cases it is within normal limits (red line) and in the months from April to August average conductivity value are optimal (blue line). Critical month is October where limits are exceeded.

B. Results from experiments - university roof models

Monitoring of the quality of RHSR from the model with ceramic roof tiles started in June 2012. Two parameters were evaluated, pH and conductivity. Water sample was taken always on the 3rd, 15th and 30th day of month from 300 liter plastic water tank.

1. Roof material: ceramic roof tiles

These were obtained by sampling and subsequent chemical analysis of water samples. pH values of water in tank during 2013 are outlined in box-plot graph on Figure 8. In 2013, average pH value equaled 7.5, maximum pH was 8.6 and minimum value reached 6.89. According to (NV SR) No. 269/2010 Z. z., pH value should range from 6 to 8.5.

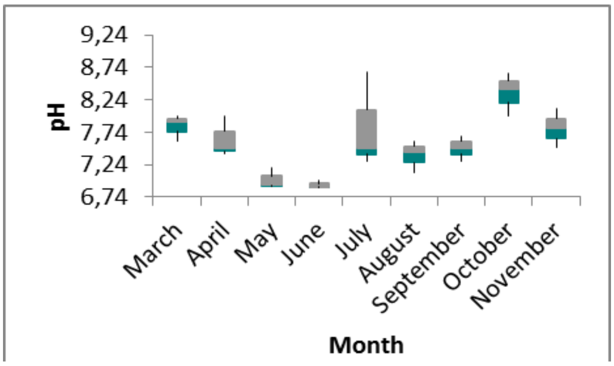

Fig. 8 pH values measured in 2013 - model with ceramic roofing

In May 2013, “first flush“ system was attached to the model with ceramic roofing. Figure 9 below shows a comparison of pH values of water from the system of “first flush“and of water from tank. Samples were taken on the same day and at the same time from the tank and from the “first flush“ system. Water from the “first flush“ is generally more acidic than RHSR from the tank, i.e. pH differs in 0.45 on average.

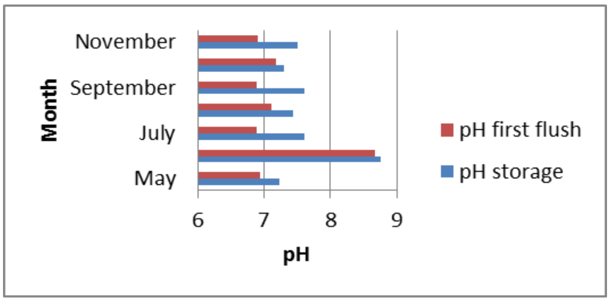

Fig. 9 Comparison of pH values of water from “first flush“ system and from tank in the model with ceramic roofing

Water conductivity values during 2013 are shown in box – plot graph on Figure 10. In 2013, conductivity values are optimal, not exceeding 50 mS/m.

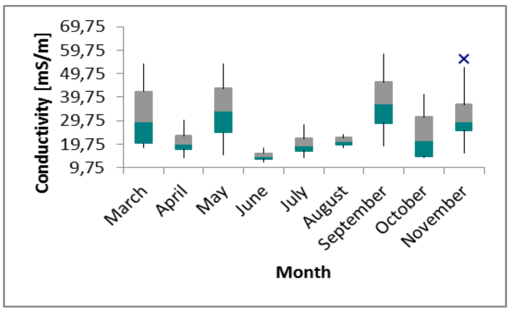

Fig. 10 Conductivity values measured in 2013 - model with ceramic roofing

2. Roof material: organic coated metal roof

Measuring of qualitative indicators for the model with organic coated metal roof began in October 2013. Water samples were collected from the "first flush" and from the tank. Samples were taken at the 3rd, 15th and 30th day in month and after large precipitation events. Figure 11 shows pH values during the monitored periods in 2013 displayed in box – plot graph. Average pH value recorded was 8, maximum pH was 8.6 and minimum 7.6.

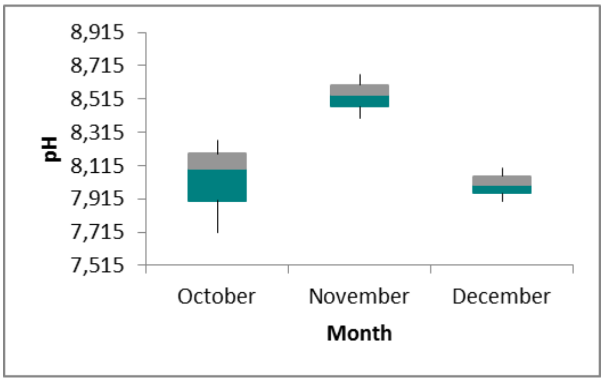

Fig. 11 pH values of rainwater from the model with organic coated metal roofing during the monitored period in 2013

Figure 12 below serves as a comparison of pH values of water collected from the "first flush" system and pH of water collected from the tank. Generally, water from the "first flush" is more acidic than SWR taken from the tank, on average the difference is 0.1.

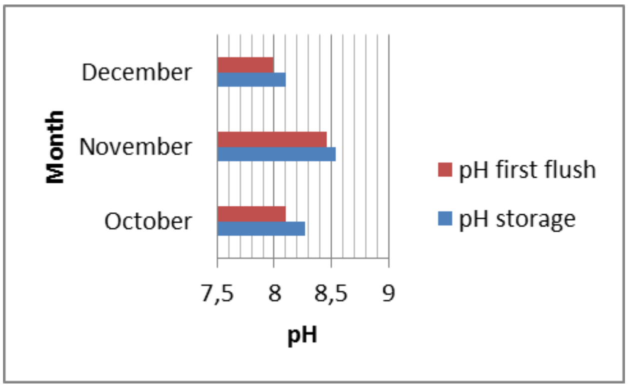

Fig. 12 Comparison of pH values of water taken from the "first flush" and from the tank for the model with organic coated metal roofing

During the 2013 monitored period, conductivity values were optimal and did not exceed 50 mS/m. Average conductivity value was 17 mS/m, maximum value reached 42 mS/m and minimum was 3 mS/m. On Figure 13 we can see a comparison of water conductivity values of water from the "first flush" and of water from the tank. Conductivity of water taken from the "first flush" is lower than of water taken from the tank, on average it is 1 mS/m, so the difference is negligible.

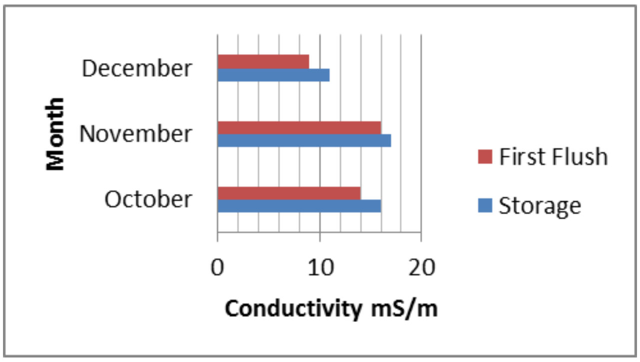

Fig. 13 Comparison of water conductivity values of "first flush" water and of water from the tank for the model with organic coated metal roofing

4 Conclusion

One of the methods of effective use of potable water sources used more frequently nowadays, not only in industrial but also in developing countries, is rainwater harvesting from surface runoff [1,4,10,11,]. The basic element of environment affecting the quality of RHSR is atmosphere. Polluted atmosphere is an important factor that degrades the quality of materials and affects the occurrence of acid rain. Each material gives different response depending on the material composition and other characteristics. Most of the materials exposed to atmosphere show sensitivity to the effect of sulfur compounds, chloride aerosols and acidity of atmospheric precipitation [4,5,6]. In this study, the results obtained through the research on the roofing materials demonstrated that organic coated metal roofing appear to be the most advantageous roofs for the collection of RHSR in the given area of Košice. Qualitative parameters of RHSR from ceramic roofings comply with the requirements on drinking water. Incorporation of "first flush" system into RHSR collecting system has significant effects on the final quality of RHSR. RHSR from "first flush" is more acidic and with higher concentration of pollutants. RHSR from model tanks meet high quality requirements on drinking water. RHSR from real building PK6 with fibrecement roof coating is, on the basis of selected indicators, suitable for irrigation and, after treatment and disinfection, also for drinking.

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