Effect of roofing material on quality of roof-harvested rainwater-correlation with rainfall events

I. Petousi[1], G. Daskalakis[1], M. Fountoulakis[2], A. Papadaki[1], C. Tsompanidis[1], E. Dialynas[2] and T. Manios[3]

[1]Enviroplan SA, 23 Perikleous & Iras Str, 15344 Gerakas Athens, Greece
[2]Dialynas SA, Troulos Kalithea Heraklion, Greece
[3]Department of Agricultural Technology, Technological Educational Institute of Crete, Estavromenos 71004 Heraklion, Greece

Abstract

Rainwater harvesting is one of the best available methods for establishing sustainable water cycles in urban developments. Although rainwater harvesting systems can be simple and inexpensive to construct, various sources of contamination within the collection system can negatively affect water quality. The main objective of the study reported herein was to examine the effect of roofing materials on the quality of rainwater harvested for domestic use. This work also provides data about the effect of antecedent dry weather period (ADWP) and precipitation rate on the quality of rainwater harvested. The results showed that granite and asphalt roof was more suitable then cement roof for rainwater-harvesting applications because of the lower concentrations of leachable pollutants. Even if, physicochemical parameters of harvested rainwater met the criteria for potable use for all examined roofs the presence of total coliforms had as a result the production of a water appropriate for use only as grey water. Finally results shown the usefulness of a first-flush system to improve the collected rainwater quality

Keywords: run off; pollution; treatment

Introduction

Water scarcity has become a serious problem due to increased urbanization, frequent droughts, and changing climate patterns. Rainwater harvesting is one of the best available methods for establishing sustainable water cycles in urban developments (Lye, 2009). Although rainwater harvesting systems can be simple and inexpensive to construct, various sources of contamination within the collection system can negatively affect water quality.

Airborne pollutants and organic substances such inert solids, dust, leaves, dead insects and bird's wastes, are added to roofs by interception and deposition (Gikas and Tsihrintzis, 2012)) while the higher roof temperatures may accelerate chemical reactions and organic decomposition of the materials and compounds that have accumulated on rooftops (Chang et al., 2004).

Contamination in harvested rainwater is also affected by roof type, including roofing materials, slope, and length (Kingett Mitchell, 2003). The installation of a device to divert the first-flush water away from the collection system may result in improvement of the harvested water quality (Mendez et al., 2011)

The main objective of the study reported herein was to examine the effect of roofing materials on the quality of rainwater harvested for domestic use. This work also provides data about the effect of dry period and precipitation rate on the quality of rainwater harvested.

Experimental

Three roofing materials were selected for the construction of lab-scale roofs: cement, asphalt and granite. Fig. 1 shows a schematic diagram of the pilot-scale design. The rain was made possible by spray emitters covered the total area for each tray. A drainage system was placed in the bottom of each tray. During the experiment, three precipitation rates (12, 22 and 34 mm/h) and five antecedent dry weather periods (1, 3, 7,14 and 28 days) were examined, for all roofs. Harvested rainwater were collected and separated in three diferrent qualities : a) first 0.2 L (S1), b) next 0.3 L (S2) and c) next 0.5 L (S3).

Figure 1. Schematic diagram and general view of lab-scale roof

Harvested rainwater samples were collected at regular time intervals during rainfall events from the three lab-scale roofs made of different materials and analyzed for pH and Electrical Conductivity (EC) according to APHA (2005). Chemical oxygen demand (COD), Total Nitrogen (TN) and Total Phosphorus (TP) were determined spectrophotometrically by use of standard test kits (Hach-Lange). Total coliforms and *Escherichia Coli* were determined using the IDEXX Quanti-Tray® enumeration procedure with Colilert-18® reagent (APHA, 2005). Statistical analyses were done with MicroCal Origin 7.0 (OriginLab).

Results and discussion

Table1 shows the characteristics of harvested rainwater during phase S1 (first flush) and phase S3. The mean pH and EC value from the cement roof (7.5 ± 0.4 and 120± 37 mg/l) were significantly higher than others. The pH of the rainwater harvested from the three types of roofs met the drinking water standard range of 6.0–9.0 (SEPAC, 2002). EC values were lower than drinking water standards set by the European Union (2.5 mS/cm; EU, 1998).

In addition, values in first flush were quite higher than next harvested rainwater indicating the usefulness of a first-flush system to improve the collected rainwater quality. Conductivity values observed were comparable to those of other studies (Vialle et al., 2011; Gikas and Tsihrintzis, 2012)

Fecal materials, mainly from birds, rodents and lizards are the primary source of pathogens in rainwater harvesting systems (Gikas and Tsihrintzis, 2012). Total coliforms (TCs) were measured in the first-flush and in the harvested rainwater. These results show that the quality of collected rainwater does not meet the standards for the microbiological parameters set by EU (1998) for potable water (0/250 ml); therefore, rainwater harvesting systems could transmit microorganisms that cause illness in humans when used as a potable water supply (Gikas and Tsihrintzis, 2012).

Table 1. Characteristics of rainwater collected from three different roof materials

Parameter	First flush (S1)			Harvested rainwater (S3)		
	Cement	asphalt	granite	Cement	asphalt	granite
pH	7.2 ± 0.4	6.8 ± 0.4	6.9 ± 0.3	7.5 ± 0.4	7.0 ± 0.5	7.2 ± 0.4
EC (μS/cm)	280 ± 43	241 ± 37	238 ± 66	120 ± 37	112 ± 56	108 ± 47
COD (mg/l)	134 ± 56	122 ± 52	126 ± 63	90 ± 86	84 ± 72	78 ± 68
TN (mg/l)	12 ± 4	10 ± 6	10 ± 4	8 ± 5	7 ± 5	8 ± 4
TP (mg/l)	0.3 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1
T. Coliforms (MPN/100ml)	124 ± 34	132 ± 41	128 ± 53	161 ± 42	158 ± 27	144 ± 52
E. Coli (MPN/100ml)	<1	<1	<1	<1	<1	<1

Conclusions

Conventional roofing materials (cement, asphalt and granite tile) were examined for their suitability to harvest rainwater for domestic use. pH, conductivity, COD, TN, TP, total coliforms and *E.Coli* were measured in harvested rainwater. The examined roofing materials provided relatively good quality rainwater in terms of physicochemical parameters. However, the microbiological quality of this water was substandard. The installation of a first-flush system improves the physicochemical quality of collected rainwater, but it cannot avoid microbial contamination of stored rainwater; The good quality of the collected rainwater, regarding its physicochemical parameters, makes the roof runoff appropriate for domestic use as grey water.

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