Analysis of Rain Water and Runoff Water Quality through The Medium of Sand and Zeolite on Green Roof based on Physical and Chemical Parameters

Sinta Agustia*, Yanuar C. Wirasembada, Satyanto K. Saptomo, Yudi Chadirin*
* Departement of Civil and Environmental Engineering, Bogor Agricultural University
** Departement of Civil and Environmental Engineering, Bogor Agricultural University

Article Info

Article history:

Received Jul 12th, 2017
Revised Aug 20th, 2017
Accepted Oct 26th, 2017

Keyword:

Green roofs
Rain water
Water quality
Zeolites

ABSTRACT

Reduced urban green space (RTH) can decrease the rainwater catchment area so that groundwater reserves are reduced. Another source of raw water that can be exploited is rainwater. Green roof can be used as a rainwater catchment area in order to increase urban green space and simple rainwater filtration by medium. Therefore, it is necessary to test the quality of rainwater and green roof runoff water. The purpose of this research is to analyze and determine the quality of rainwater and green roof runoff water with sand and zeolite as media. The water quality standard reffered to Government Regulation No. 82/2001 regarding the water quality management and water pollution control. Determination of water quality are using STORET method refferred to Ministry of environment's Decree No. 115/2003 regarding the guidance of water quality status. Rain water and green roof runoff water with all various media are classified as lightly polluted and have potensial as a raw water source for daily consumptions.

Corresponding Author:

Yudi Chadirin,
Departement of Civil and Environmental Engineering,
Bogor Agricultural University,
Jl. Raya Darmaga Kampus IPB Darmaga Bogor 16680 West Java, Indonesia
Email: yudi@gmail.com

I. INTRODUCTION

The needs of residential and industrial facilities in urban area are increasing as the population grows. One consequence is the change of land use from vegetated land to residential and industrial area. The impact of changes in land use is reduced green space (RTH) in Indonesia. Alternative to overcome problem that is with using a green roof. Green roofs can be defined as buildings whose surfaces are covered by plants or vegetation, either in whole or in part. Green roof consists essentially of vegetation layer, substrate layer (water storage and vegetation growth medium), and drainage layer (for runoff water) (Mentens et al., 2006).

Besides being used to increase the availability of green space, green roof can be functioned for rainwater absorption into its medium. Based on research from Adha (2015), the comparison of green roof with concrete roof, indicates that green roof media able to retain rain water with 83.32% of retention. Nowadays, citizens take advantages of rainwater through rainwater harvesting on the roof that is channeled through the gutters and then collected to the tank for daily consumptions. The rainwater collection system can be divided into several components, namely the catchment area (artificial and natural), drainage, initial filtration, storage, and purification (Che-Ani et al., 2009).

However, the surface runoff and green roof runoff water contain various constituents. Green roof is a vegetated buffer and thus should adsorb pollutant. However, a green roof can potentially release pollutants from the growth media, litters, or fertilizer. Thus, the runoff may contain various metals, organics, and inorganic ions. The major factors that impact green roof runoff water quality are the growth media, vegetation species, precipitation properties, irrigation amount and timing, and plant fertilization practices (Yanling Li and Babcock, 2014).

Rain water and green roof runoff water can be used as an alternative source of raw water if known its quality. Therefore, it is necessary to test the quality of both. The purpose of the research is to analyze and

determine the rain water and green roof runoff water based on STORET (STOrage and RETrieval) refferred to Ministry of environment's Decree No. 115/2003 regarding the guidance of water quality status.

II. RESEARCH METHODOLOGY

2.1. Study site

The reasearch was conducted at Center for Information and Agricultural Technology Building (PITP), Faculty of Agricultural Technology, IPB, Bogor. Green roof modelling was constructed on the rooftop of PITP building. Green roof was made in wooden box from multiplex with 1 m x 1m x 0,3 m in dimension.

The study area consisted about rain water quality, runoff water from two variants of growing media in greenroof and bare soil as a control without plants (Table 1).

Tabel 1 Variant of growing media in green roof

Name	Crops	Growing media (from soil surface)	Thickness
B1	Water spinach (*Ipomoea reptans* Poir)	1. Soil 2. Sands 3. Zeolites 4. Filter fiber 5. Versicell drainage	1. 12 cm 2. 7 cm 3. 7 cm 4. 1 cm 5. 3 cm
B2	Water spinach (*Ipomoea reptans* Poir)	1. Soil 2. Sands 3. Filter fiber 4. Versicell drainage	1. 12 cm 2. 14 cm 3. 1 cm 4. 3 cm
B3	Without crops (control)	1. Soil 2. Sands 3. Filter fiber 4. Versicell drainage	1. 12 cm 2. 14 cm 3. 1 cm 4. 3 cm

The total thickness of sand and zeolite that is 14 cm with a ratio of 1: 1. The size of zeolite that used is zeolite number 3 with the size of 2-3 cm or mesh 6-8. In B1 and B2 was added compost as a source of nutrients for plants. Compost was on the first day of cultivation with balance proporsion.

2.2. Data analysis

The measurement of water quality for rain water and green roof runoff water are based on physical and chemical parameters. Physical parameters consist of temperature, total suspended solid (TSS), and total dissolved solid (TDS) while chemical parameters consist of power of hydrogen (pH), sulphate [SO_4^{2-}], ammonia [NH_3-N], nitrate [NO_3-N] and nitrite [NO_2-N]. The laboratory analyses of the water quality parameters were determined according to the standard of water quality status in Indonesia, there was Government Regulation No. 82/2001 regarding the water quality management and water pollution control (Table 2).

Table 2 Selected parameters and threshold

	No	Parameters	Unit	Threshold (WQL)
Physical	1	Temperature	^{0}C	±3^{0}C from
	2	Total suspended solid (TSS)	mg/L	50
	3	Total dissolved solid (TDS)	mg/L	1000
Chemical	1	Power of hydrogen (pH)	-	6-9
	2	Sulphate [SO_4^{2-}]	mg/L	400
	3	Ammonia [NH_3-N]	mg/L	0,5
	4	Nitrate [NO_3-N]	mg/L	10
	5	Nitrite [NO_2-N].	mg/L	0,06

The determination of water quality status based on STORET (Storage and retrieval) refferred to Ministry of environment's Decree No. 115/2003 regarding the guidance of water quality status. The basic concept of

STORET is to compare between water quality data and its standard. As a result, status of water quality depends on the score of water sampling based on the following classification system (Table 3).

Table 3 Water classification based on US-EPA

Class	Score	Classification
A	0	Not polluted (NP)
B	-1 s/d -10	Lightly polluted (LP)
C	-11 s/d -30	Moderately polluted (MP)
D	≥ -31	Highly polluted (HP)

Sources: Environment Ministerial Decree No. 115/2003 (Ministry of Environment of Indonesia, 2003)

Tabel 4 Values measuring

Parameters	Value	Parameters		
		Physics	Chemical	Biology
<10	Max	-1	-2	-3
	Min	-1	-2	-3
	Average	-3	-6	-9
≥10	Max	-2	-4	-6
	Min	-2	-4	-6
	Average	-6	-12	-18

Sources: Environment Ministerial Decree No. 115/2003 (Ministry of Environment of Indonesia, 2003)

III. RESULTS AND DISCUSSION.

a. Physical parameters

Threshold based on Government Regulation No. 82/2001 for temperature are ±3°C from air temperature. In over all, temperature of rain water (PW) and green roof runoff water was complied to threshold. Temperature affect to the solubility of gases in rainwater. The condition of rainwater quality was influenced by the condition of pollutants in the air which is usually gas-shaped. When rainfall, the rainwater had a direct contact with the air, then the pollutants in the air dissolved and carried down with rain water.

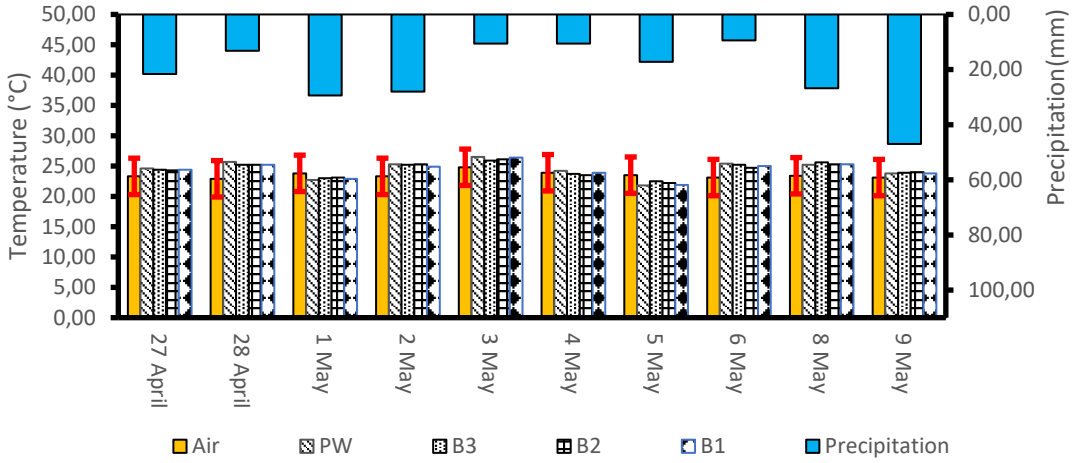

Figure 2 Temperature of Rain Water and Green roof runoff water

Total suspended solids can include clays, silts, fine organic debris, and other particulate matter in suspension. Green roofs increased suspended solids after installation. Based on study, TSS concentration in rain water and green roof runoff water are comply to threshold on the first watering event by rain. TSS from rain water

and green roof runoff water all various media are not comply to threshold from the second watering event afterwards. Morgan et al. (2011) concluded that the plants were only able to reduce TSS and turbidity during the first flush and have no significant impact on the values afterwards. Long-term impacts have not been evaluated. TDS are soluble substances in the form of chemical compounds and other material. From the study, TDS in rain water are comply to Government Regulation No. 82/2001, while green roof runoff water from all various media are not comply (Fig 3) from the first to third watering events. From fourth to the last watering events, TDS from all various media was decreased and complied threshold. The higher of dissolved solids in water due to the addition of fertilizer and the organic matter content to the soil. The decreased of dissolved solids caused by watering events from rain water.

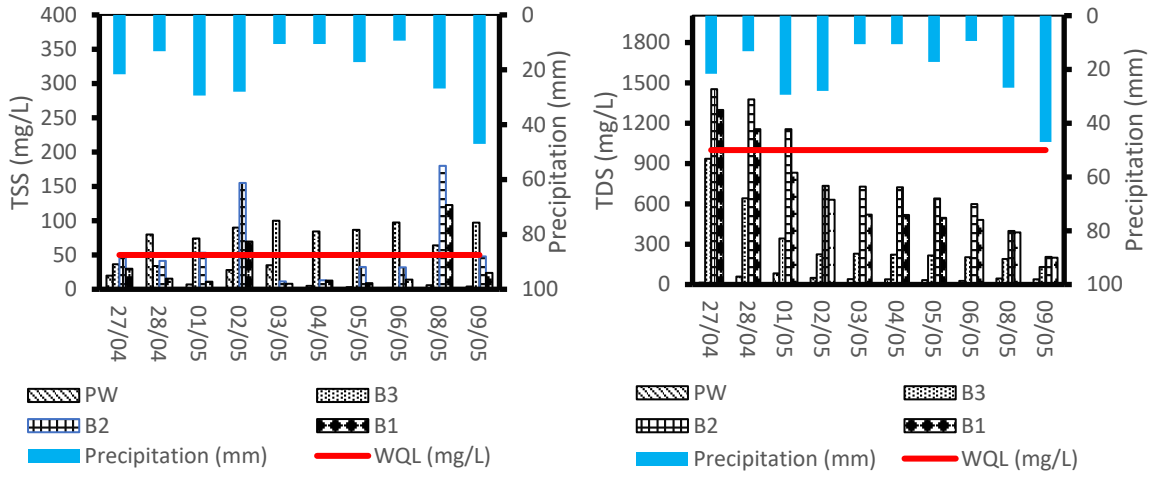

Figure 3 TSS and TDS from Rain Water and Green roof runoff water

b. Chemical Parameters

Power of Hydrogen (pH) is a unit of measurement that describes the degree of acidity, the alkalinity of a solution, especially as an indicator of water quality. pH of rain water and green roof runoff water from all various media are comply to threshold based on Government Regulation No. 82/2001 (Fig 4). Rain water water with pH <5.6 indicates the presence of acid rain events. While the results show that the incidence of rain water was not acid rain.

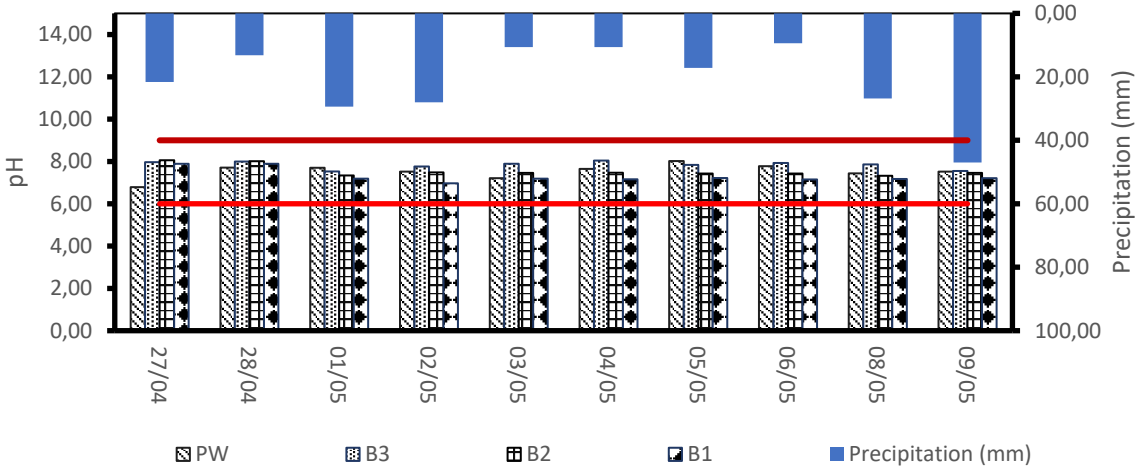

Figure 4 pH from Rain Water and Green roof runoff water

Sulphate in rain water and green roof runoff water are comply to threshold 400 mg/L. Nitrate in rain water and green roof runoff water are comply to threshold 10 mg/L (fig 5). Two pollutants that play an important role in the occurrence of acid rain are SO_x and NO_x. Both pollutants can react with ozone (O_3) as an oxidant that

converts SOx and NOx to sulphate and nitrate. Sulphate will react with rain water to form sulfuric acid causes acid rain. The sulfur in the soil is absorbed by the plant in sulphate form (SO_4^{2-}) and only a small part of the sulfur in SO_2 gases are absorbed directly by the plant from the soil. The S-form is an inorganic S that is active in the soil. Inorganic sulfur is produced from the decomposition of organic compounds containing S and fertilizer (Engelstad 1997).

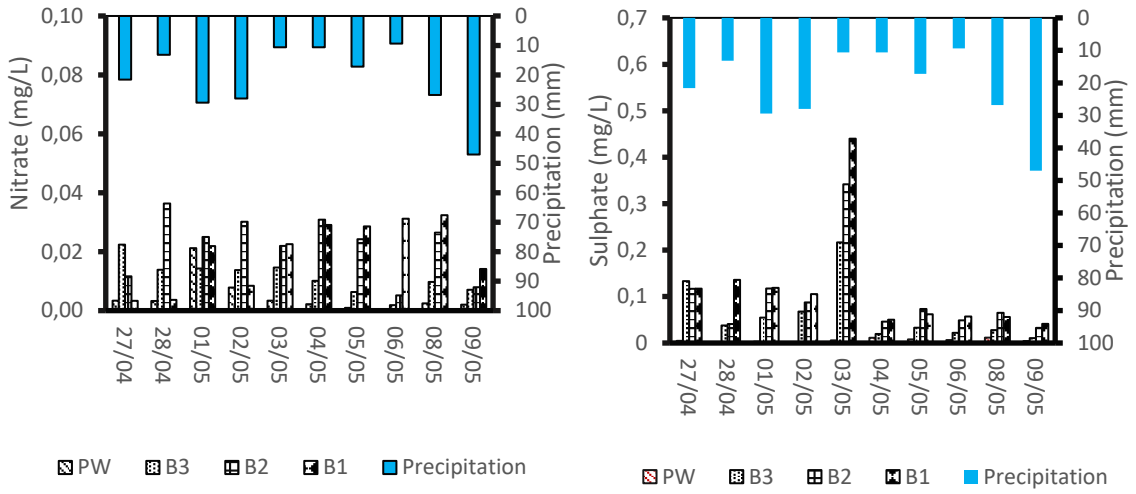

Figure 5 Nitrate [NO_3-N] and Sulphate [SO_4^{2-}] from Rain Water and Green Roof Runoff Water

Nitrite in rain water are comply to threshold 0,06 mg/L, but green roof runoff water from all various media are did not complied. Ammonia in rain water and green roof runoff water are comply to threshold 0,5 mg/L (Fig 6) The concentration of ammonia and nitrite in the atmosphere are influenced by nitrogen (N_2). Nitrogen is derived from NO_2 which is a pollutant in the atmosphere. Pollution of NO_2 in the atmosphere is mainly derived from combustion-discharged exhaust gases from stationary power station generators or engines that using natural gases fuel. The presence of nitrate content (NO_3-N), nitrites (NO_2-N), and ammonia are closely related to the nitrogen cycle. Ammonia is produced from the ammonification process of the organic N form obtained the N_2 fixation from the atmosphere by microorganisms in the soil. In addition, N elements are also obtained from the content of fertilizer used. Organic nitrogen unndergoes a hydrolysis reaction that producing ammonia which is a nitrogent source for bacteria. The oxidation process then occurs by *Nitrosomonas* bacteria, converting ammonia to nitrites, then *Nitrobacter* bacteria oxidize nitrites to nitrates, named as nitrification processes (Aswadi 2006).

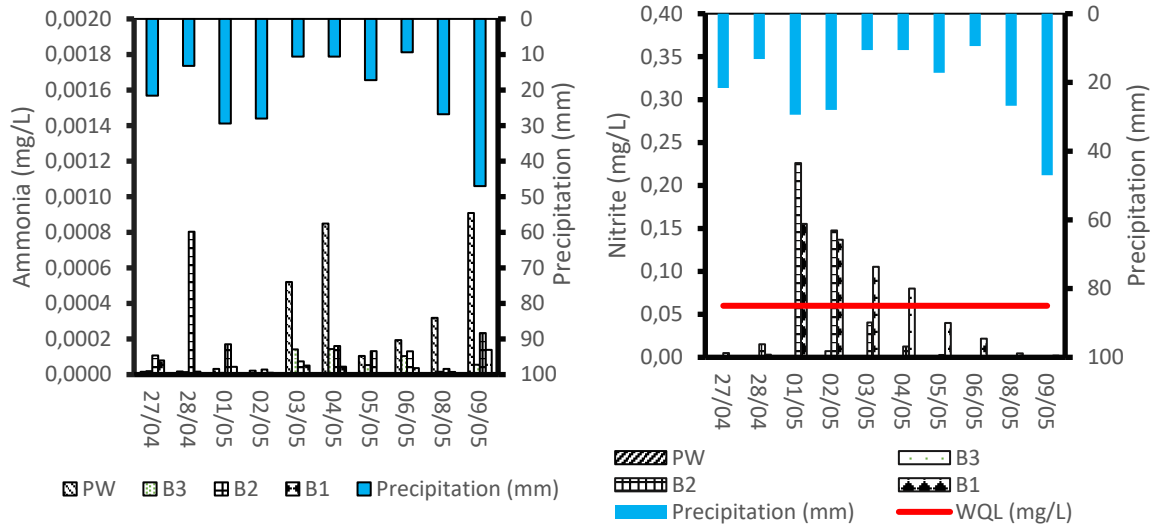

Figure 6 Ammonia [NH_3-N] and Nitrite [NO_2-N] from Rain Water and Green roof runoff water

c. Rain water and Green Roof Runoff Water Quality Assesment

The quality of rainwater are not comply to threshold on the physical parameters, there was TSS. The maximum TSS concentration of all the results of the study did not complied the quality standard, so it given the value -1. Total value for rainwater quality is -1 (Table 5). The status of rain water quality was at category "B" indicates that the water was lightly polluted (Table 3). The greenroof water media control (B3), are not complied to threshold on the physical parameters, there was TSS. The maximum and average in TSS concentration of all the results of the study did not complied the quality standard, so it given the value -1 and -3. Total value for green roof control is -4 (Table 5). The status of green roof control was at category "B" indicates that the water was lightly polluted (Table 3).

Table 5 Assesment of Rain Water and Green roof runoff water (Control) Quality

Parameters		Rain water Water				B3 (Green roof control)			
		Max	Min	Average	Total	Max	Min	Average	Total
Physical	Temperature	0	0	0	0	0	0	0	0
	TDS	0	0	0	0	0	0	0	0
	TSS	-1	0	0	-1	-1	0	-3	-4
Chemical	pH	0	0	0	0	0	0	0	0
	Nitrite	0	0	0	0	0	0	0	0
	Nitrate	0	0	0	0	0	0	0	0
	Ammonia	0	0	0	0	0	0	0	0
	Sulphate	0	0	0	0	0	0	0	0
				Total	-1			Total	-4

The greenroof water in media without zeolites (B2), are not complied to threshold on the physical and physical parameters, such as TDS, TSS, and nitrite. The maximum and average in TSS concentration of all the results of the study did not complied the quality standard, so it given the value -1 and -3. The maximum in TDS concentration did not complied to threshold , so it was given a value of -1. The maximum in nitrite concentration did not complied to threshold , so it was given a value of -2. Total value for green roof control is -7 (Table 6). The status of green roof control media without zeolites (B2) at category "B" indicates that the water was lightly polluted (Table 3). The greenroof water in media with zeolites (B1), are not complied to threshold on the physical and chemical parameters, such as TDS, TSS and nitrite. The maximum in TSS adn TDS concentration of all the results of the study did not complied the quality standard, so it given the value -1. The maximum in nitrite concentration did not complied to threshold , so it was given a value of -2. Total value for green roof control is -4 (Table 6). The status of green roof control media without zeolites (B2) at category "B" indicates that the water was lightly polluted (Table 3).

Tabel 6 Assesment of Green roof runoff water Quality with Sands and Zeolites Media

Parameters		B2 (without zeolites)				B1 (zeolites)			
		Max	Min	Average	Total	Max	Min	Average	Total
Physical	Temperature	0	0	0	0	0	0	0	0
	TDS	-1	0	0	-1	-1	0	0	-1
	TSS	-1	0	-3	-4	-1	0	0	-1
Chemical	pH	0	0	0	0	0	0	0	0
	Nitrite	-2	0	0	-2	-2	0	0	-2
	Nitrate	0	0	0	0	0	0	0	0
	Ammonia	0	0	0	0	0	0	0	0
	Sulphate	0	0	0	0	0	0	0	0
				Total	-7			Total	-4

Additions of compost to green roof B2 and B3 was increasing nitrite and dissolved solids consentration. Green roof growing media are typically engineered to include nutrients in order to promote plant growth. This is

evident from the much higher levels of phosphorus, total Kjeldahl nitrogen (TKN), and potassium in green roof (Seters et al. 2009). The higher of dissolved solids indicates there were nutrients from compost had been dissolved by rain water flushing.

CONCLUSION

Rain water water was complied almost in all parameters, except suspended solids (TSS). Green roof runoff water from all various media were complied in temperature, pH, nitrite, sulphate, and ammonia, whereas TSS, TDS and nitrite are not complied. Total value for rainwater quality is -1 was at category "B" indicates that the water was lightly polluted. Total value for green roof control is -4 was at category "B" indicates that the water was lightly polluted. Total value for green roof control is -7 was at category "B" indicates that the water was lightly polluted. Total value for green roof control is -4. The status of green roof control media without zeolites (B2) at category "B" indicates that the water was lightly polluted.

REFERENCES

[1] Morgan, S.; Alyaseri, I.; Retzlaff, W. Suspended solids in and turbidity of runoff from green roofs. International Journal of Phytoremediation [Internet]. 2011; 13:179-193. Available from : http://www.tandfonline.com/doi/abs/10.1080/15226514.2011.568547.
[2] Engelstad OP. Teknologi Dan Penggunaan Pupuk (Edisi Ketiga). Yogyakarta (ID) : Gadjah Mada University Press. 1997.
[3] Adha H. 2015. Analisis Retensi Air Hujan pada Media Green Roof dalam mengurangi Limpasan Air Hujan di Gedung PITP IPB, Bogor[Skripsi]. Bogor(ID): Institut Pertanian Bogor.
[4] Aswadi M. Pemodelan fluktuasi nitrogen (nitrit) pada aliran sungai palu. Jurnal Smartek. 2006; 4(2):112-125.
[5] Che-Ani AI, Shaari N, Sairi A, Zain MFM, Tahir MM. Rainwater harvesting as an alternative water supply in the future. European Journal od Scientific Research [Internet]. 2009 Jan; 34(1):89-96. Available from : http://www.eurojournals.com/ejsr.htm
[6] Seters TV, Rocha Lisa, Smith D, and MacMillan G. Evaluation of green roofs for runoff retention, runoff quality and leachability. Water Qual. Res. J. Can. 2009 . 44(1): 33-47.
[7] Mentens J, Raes D, Hermy M. Green roof as a tool for solving the rainwater runoff problem in the urbanized 21st century. Landscape and Urban Planning. 77 (1): 217-226.
[8] Yanling Li and Babcock. Green roofs against pollution and climate change. A review. Agron. Sustain. Dev. 2014. 34:695-705.