The Effect Analysis of the Decentralized Rainwater Management System in Korea Apartment Complexes

Kyung-Hak Hyun[1], Sung-Sick Ahn[2], Joung-Joo Choi[2], Soon-Young Park[2]

[1]Associate Specialist, HURI (Housing & Urban Research Institute) Environment and Energy Research Team in KNHC (Korea National Housing Corporation), Korea (khhyun@knhc.co.kr, Fax : 82-31-738-4700)

[2]Research Assistant, HURI Environment and Energy Research Team in KNHC, Korea

Abstract: In this study, the effect of the decentralized rainwater management facility in Korean apartment complexes is analyzed. The experimental site is Yongin S 1 BL, and underground rainwater storage tank, infiltration barrel and infiltration trench are applied. Rainwater flows through rainwater management facility and then it is stored or infiltrated into the underground. Experiment is run with the natural rainfall and artificial rainfall. Monitoring it leads, rainwater runoff reduction and pollution loads reduction effect are analyzed. Runoff reduction rate is compared with the runoff discharge which it follows in rainfall and it analyzed. Pollution loads reduction rate is analyzed with the water quality test of the inflow and the outflow.

Keywords: decentralized rainwater management, effect of rainwater management facility, underground rainwater storage tank, infiltration barrel, infiltration trench.

1. Introduction

In general, rainwater flows to the river, infiltrates into the ground, and evaporates. But, because of impermeable pavement and centralized rainwater management facilities expanded with the urbanization, natural hydrologic cycle is broken. Underground water level keeps dropping and many bad effects such as drying streams, urban heat island and so on are occurring. And then, travel time of rainwater is decreased, and total runoff is increased. Consequently, disaster due to a flood in urban is repeated annually (Hyun et al., 2005).

Recently, decentralized rainwater management is required because of the flood disaster reduction and restoration of hydrologic cycle of the city. Decentralized rainwater management facility will be able to substitute centralized rainwater management facility. The laws about rainwater and water resources are legislating. Seoul and local autonomies are encouraging the application of decentralized rainwater management facility through an ordinance.

6,450,000 ones(52%) of the total 12,360,000 households of dwelling form are an apartment in Korea(Hyun et al., 2006). Therefore, it is necessary to apply and study of rainwater management facility in Korea apartment complexes. It is possible to build the eco-friendly complexes by the hydrologic cycle restoration, make urban microclimate and develop new water resources when the rainwater management facility was applied to the apartment complexes.

Water Practice & Technology Vol 3 No 2 © IWA Publishing 2008 doi: 10.2166/WPT.2008033

The aim of study is to make the guidance on application of rainwater management facility in Korean apartment complexes, and it analyzes the application effect of rainwater management facility after selecting the experimental site. The experimental site is Yongin S 1BL, and the underground rainwater storage tank, infiltration barrel and infiltration trench are applied.

2. Methods

Rainwater management facility such as open channel, infiltration barrel, infiltration trench and infiltration pool and etc. is easier to be applied to the apartment complexes. In this study, underground rainwater storage tank, infiltration barrel and infiltration trench are chosen, and applied to an apartment complex in Yongin.

2.1 Experimental site

In this study, the experimental site is selected S 1BL in Yongin, GyeongGi. S 1BL is a five-year tenant apartment complex and it was occupied in April, 2006. The experimental site is a community housing complex which consists on total 414 households, 7 houses, and the ground area is 16,315 ㎡, the floor space index is 192%, and the afforestation rate is 29.6%.

2.2 Underground rainwater storage tank

Underground rainwater storage tank stores the roof rainwater in rainy season, and it utilizes water for wall fountain or gardening and road sprinkling in complexes. The facility applies to underground. Then, ground is utilized efficiently, for example ground would use the parking lot, park and playground.

The stored roof rainwater in the underground rainwater storage tank applied to use for supplementary water of wall fountain. The upper ground of the underground rainwater storage tank is used as a children's playground to increase the utilization rate of the site. The underground rainwater storage tank consists of rainwater precipitation tank, sand-filter supply tank and filtrate storage tank, the total storage volume of rainwater is $101m^3$. It analyzed the precipitation of the experimental site for recent 10 years and decided the monthly collected rainwater of underground rainwater storage tank and presented how to operate it. Also, security of water quality was evaluated by the water quality analysis of underground rainwater storage tank compares with Living Water Standard and Grey Water Standard.

2.3 Infiltration barrel & Infiltration trench

Infiltration barrel and infiltration trench fill side of the body with gravel and then rainwater infiltrates through side or bottom. It has conveyance by connecting with the existing sewer pipe. Generally, it applies to green zone of around building and ground which has good water permeability. If the infiltration facility is only used, it can’t have sufficient runoff reduction effect and decreasing effect of non-point pollution source. So it has the advantage under the connection of two facilities and installation with rainwater management facility such as open channel, infiltration pool. It needs regular clean and maintenance because clogging of the gravel layer could happen by influx as sand, leaves and etc.

In this study, infiltration barrel and infiltration trench applied to reduce runoff of rainwater and the first flush in the parking lot. Infiltration barrel and infiltration trench is connected with the existing sewer pipe. Applied size of the infiltration barrel is 0.95×1.10× 1.00(H:W:L(m)) and infiltration trench is 0.2×0.7×0.6(Φ:H:W(m)). A Basin is 500m^2 of the parking lot. Two infiltration barrels and 36m of infiltration trench applied to green zone by the side of the parking lot. It decreased the runoff and the first flush of the parking lot.

Experiments about natural rainfall and artificial rainfall are operating together. We calculated the quantity of inflow which was based on the precipitation of Korea Meteorological Administration(KMA) and measured quantity of outflow through the flowmeter installed in the end of applied facility. We analyzed the runoff reduction effect by difference between the quantity of inflow and outflow. We also analyzed the reduction effect of non-point pollution source through comparing the water quality of inflow with the water quality of outflow which is passed by rainwater management facility.

Figure 1. Detail drawing of the applied infiltration barrel and infiltration trench.

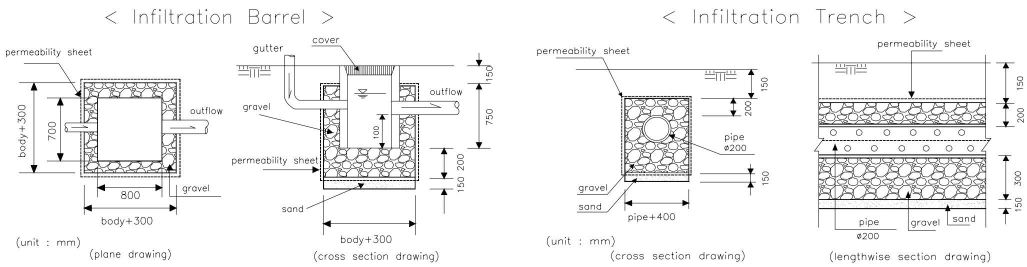


Figure 2. Before and after the application of infiltration barrel and infiltration trench.

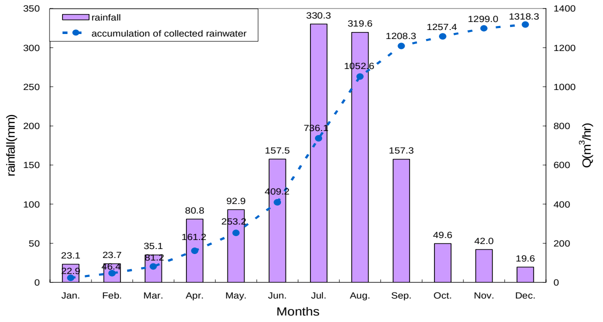
3. Results and discussion

In this study, it analyzed the application effect of underground rainwater storage tank, infiltration barrel and infiltration trench. Both experiments about rainfall and artificial rain are operating together and it analyzed the reduction effect of runoff and non-point pollution source.

3.1 Underground rainwater storage tank

It analyzed the monthly total precipitation of Suwon for recent 10 years and the average of the total precipitation is 1331.7mm(KMA, 2006). The rainfall pattern is concentrated in July and August. Total precipitation of July and August's - 649.9mm - is similar to one of other 10 months - 681.8mm. This is about 49% of the total precipitation a year. It calculated monthly collected rainwater and accumulated one which base on average of monthly precipitation in Yongin S 1BL. The basin of underground rainwater storage tank is 1,100m^2 of 4 roofs, and the coefficient of runoff on the roof is 0.9.

Figure 3. The average of rainfall and accumulation of collected rainwater.



If annual-rainwater was collected wholly, rainwater which is about 1,300ton/year could store in underground rainwater storage tank by rational formula. So, if rainwater of 100ton was stored in the underground rainwater storage tank, it could use about 13 times a year. However, in fact, the stored rainwater in the underground rainwater storage tank can be operated about 8 times a year. It is the reason underground rainwater storage tank is not to operate during the winter season(Dec., Jan., Feb.). The total storage volume is about 640ton during the rainy season(Jul., Aug.), but just 200ton(Jul., Aug.) is used during severe rain storm owing to extra rainwater by-pass to the existing sewer pipe before influx in the underground rainwater storage tank. Therefore, the working period is 9 months from March to November, and it could be used about 800ton rainwater of 1300ton.

The stored rainwater in the underground rainwater storage tank was analyzed 20 water properties as total colony counts, heavy metals and pH according to the Living Water Standard. The Living Water Standard shows that total colony counts are under 100CFU/mL, and total coliforms are under 5,000cell/100mL. Its result shows that the former is detected 4CFU/mL and the latter is 2cell/100mL, but it is suitable for water standard. The 19 including total colony counts of 20 parameters are suitable for the standard, but pH, 10.2, is not. The pH of rainwater in the underground rainwater storage tank as well as one from a roof is 11. It seems owing to the material or waterproofing of the apartment roof. Therefore, it seems that it would operate rainwater in the underground rainwater storage tank well, if the security of pH was ensured.

The basin has influence on the pH of rainwater. The push-concrete is the last paving materials of the apartment roof. Therefore, the pH of rainwater is showed high by the concrete. They said that the rainy water is acidic, but collected one through basin is neutral or alkaline(Han et al., 2003). The density of Ca^{2+} increased when the rainwater passed the concrete. It was eluted from $CaCO_3$ and then the pH of rainwater was increased.

Rainwater on roof flows through ‘gutter → coupling pipe → inflow manhole → storage tank’. <Table 1> is a result of the water quality analysis in gutter, inflow manhole, and storage tank. Compare with the Grey Water Standard, pH is not satisfied because it showed the high range of 9.57~ 9.70. But COD, Turbidity, Appearance, and Smell are suitable for standard.

Table 1. Water quality analysis (average).

Parameters	Gutter	Inflow manhole	Storage tank	Grey Water Standard
pH	9.57	9.64	9.70	5.8~8.5
COD(mg/L)	40.70	11.45	10.45	below 20 mg/L
SCOD(mg/L)	38.20	9.35	8.05	-
SS(mg/L)	10	10	15	-
TN(mg/L)	42.40	0.60	1.95	-
TP(mg/L)	4.10	0.88	0.72	-
Alkal.(mg/L)	28	53	59	-
Turbidity(NTU)	4.63	2.19	1.68	below 2NTU
Smell	OK	OK	OK	no unpleasant smell
Appearance	OK	OK	OK	no unpleasant feeling

3.2 Infiltration barrel & Infiltration trench

In the natural rainfall experiment, we analyzed the reduction effect of runoff and peak runoff, it is based on 10 data from June and July in 2006. The inflow calculated by rational formula based on the precipitation data of KMA. Portable ultrasonic flowmeter installed at the sewer manhole located the bottom of rainwater management facility. The outflow passed through the rainwater management facility measured by flowmeter.

Rainwater flows in the gravel layer around infiltration barrel and infiltration trench and temporarily to be detention, after that slowly infiltrates. When the rainwater exceeds the detention volume of the gravel layer, it flows by the existing sewer pipe which is connected the bottom of the rainwater management facility. The soil sample was picked from the experimental site and worked the indoor hydraulic conductivity test. The result showed that hydraulic conductivity is 5.5×10^{-4}cm/sec. So it seems that 0.8ton/hr rainwater could store and infiltrate through the gravel layer around infiltration barrel and infiltration trench.

As <Table 2>, runoff reduction rate is very different according to the precipitation, the rainfall duration and the antecedent non-rainfall day. The total outflow in comparison with the total inflow decreased of 39~ 89%, and peak runoff did 10~85%. This result is similar to the outflow reduction effect of 65~98% by a field measuring which installed infiltration barrel in 10 models areas as Sungnam, Osan and so on(NIDP, 2003).

Table 2. Runoff reduction rate in 2006 summer season.

	Total Inflow (m^3/hr)	Total outflow (m^3/hr)	Runoff reduction rate (%)	Rainfall (mm)	Rainfall duration (hr)	Rainfall intensity (mm/hr)	Antecedent non-rainfall day (days)
6 / 14	34.6	21.2	38.8	77.0	16	4.8	2
6 / 21	2.4	1.0	57.7	9.0	7	1.3	2
6 / 30	9.0	0.9	89.1	14.5	5	2.9	0
7 / 07	14.2	3.9	71.8	25.5	9	2.8	0
7 /10	5.4	0.7	86.2	12.0	8	1.5	0
7 /12	38.3	20.9	45.3	85.0	23	3.7	0
7 /13	6.8	1.1	83.9	15.5	11	1.4	0
7 /15	7.8	4.6	41.4	17.5	7	2.5	1
7 /16	76.3	36.7	51.9	170.0	24	7.1	0

7 /17	6.1	3.1	49.2	13.5	12	1.1	0

Figure 4. Runoff reduction rate in 2006 summer season.

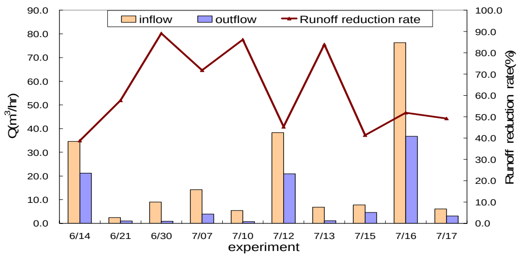
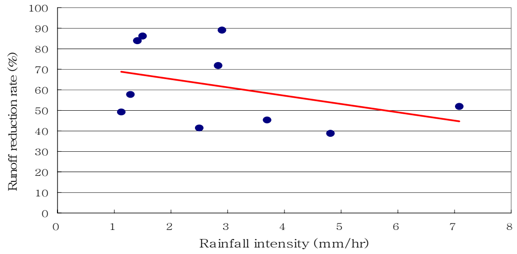
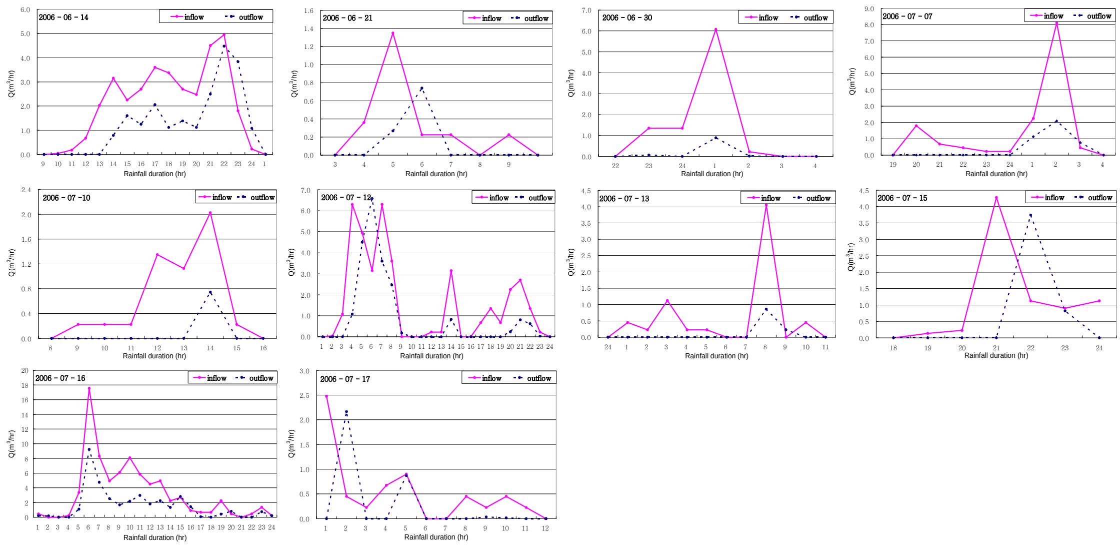


Figure 5. Rainfall duration – runoff reduction rate.



It confirmed that the outflow decreased by applying infiltration barrel and infiltration trench. On June 14, antecedent non-rainfall day is 2 days and rainfall duration is 15 hours, it rained 77mm totally. The rainfall started at 9 a.m. and the first outflow occurred at 1 p.m.. So the inflow of 2.93m^3 did not flow out by infiltration barrel and infiltration trench for 4 hours. This result means that it decreases the water pollution loads by the reduction of first flush. Runoff reduction rate decreased about 40%(13.45m^3/hr) with inflow is 34.65 ㎥/hr and outflow is 21.20m^3/hr. On July 10, antecedent non-rainfall day is none and rainfall duration is 9 hours, it rained 12mm totally. The runoff reduction rate decreased about 63% (4.65m^3/hr) with inflow is 5.40 ㎥/hr and outflow is 0.7m^3/hr. The peak runoff decreased about 63%(1.28m^3/hr).

Figure 6. Analysis of the inflow and the outflow.



Artificial rainfall experiment is working because continuous natural rainfall experiment is not enough. It worked 5 times and analyzed the reduction effect of non-point pollution source by comparison between outflow of water in the parking lot and one through the rainwater management facility.

In the case of test No.5, antecedent non-rainfall day is 30days, and it rained 0.5mm. When it compared between the density of rainwater from the parking lot and one from the rainwater management facility, COD decreased about 60% from 47.6 ㎎/L to 19.4l ㎎/L. SS did not detect from 20 ㎎/L to 0 ㎎/L. The early pollution density of rainwater is high because antecedent non-rainfall day is long with 30 days. When the antecedent non-rainfall day is long, travel time is delayed. Travel time showed about 35~80 minutes from the parking lot to the underbody manhole of the rainwater management facility. When the antecedent non-rainfall day is short, it is 30 minutes but one is long with 30 days, it is 80 minutes. It seems that travel time is influenced by the saturation or aridity of soil during no raining season.

Table 3. Water quality analysis of the Inflow(Gutter) and the Outflow(Manhole).

Experiments		time	COD (mg/L)	TP (mg/L)	TN (mg/L)	SS (mg/L)	SCOD (mg/L)	Antecedent non-rainfall	Outflow lag time (min)
No.1	Inflow	10:30	1.2	0.09	0.2	20	0.8	0 days	41
	outflow	11:11	2.0	0.20	0.2	10	0.9	runoff	
No.2	Inflow	11:00	27.7	0.10	3.3	75	.	1 days	35
	outflow	11:35	7.2	0.06	1.1	5	.	runoff	
No.3	Inflow	10:30	8.5	0.07	0.5	0	6.7	2 days	40
	outflow	11:10	0.2	0.12	0.4	0	0.1	runoff	
No.4	Inflow	12:06	90.6	0.52	4.3	10	68.9	6 days	44
	outflow	12:50	4.6	0.12	1.2	10	0.4	runoff	
No.5	Inflow	10:42	47.6	0.45	7.0	20	40.5	30 days	78
	outflow	12:00	19.4	0.21	3.3	0	10.3	runoff	

On the whole, the pollution level of outflow is high in the early time. When the outflow in a parking lot flows out through the infiltration system, its pollution level is remarkably decreased. Also, the pollution level is low when the antecedent non-rainfall day is short and precipitation is little. In case of the surface is not clean like a parking lot, the pollution level of first flush is high. So it was judged that it needs to decrease the non-point pollution source by installing rainwater management facility such as infiltration barrel and infiltration trench.

4. Conclusion

The application of the decentralized rainwater management facility is necessary for eco-friendly complexes construction and hydrologic cycle restoration in the apartment complexes which occupies about 50% of the domestic house. In this study, it chose the rainwater management facility which is easy to apply such as underground rainwater storage tank, infiltration barrel and infiltration trench. Then it was applied to an apartment complex in Yongin. The effect of rainwater management facility analyzed, and the result follows that.

Underground rainwater storage tank applied to utilize the supplementary water of the wall fountain. Its upper ground is used as a children's playground to increase the utilization rate of the site. If it uses the detention rainwater with 100ton from the underground rainwater storage tank, it is possible to use about 800ton a year. When the water quality analyzed in the underground rainwater storage tank, almost all parameters are good except pH. It seems that pH is influenced by push-concrete last paving material of apartment roof. When the rainwater passes the surface of concrete, Ca^{2+} is erupted from $CaCO_3$ and then pH becomes high. When the rainwater of roof in the apartment complexes used, the last paving material of roof would be good not to use the concrete.

When the runoff reduction rate analyzed in 2006 summer season, total outflow in comparison with total inflow is decreased 39~89%. It also has the effect of the outflow delay about 1~5 hours from the first outflow in the parking lot to one in rainwater management facility. It means that it makes rainwater detention and infiltration to reduce the runoff at rainy point through rainwater management facility and can control a non-point pollution source. Artificial rainfall experiment analyzed the pollution loads reduction with the outflow in the parking lot and the rainwater management facility. Experiment worked 5 times and the early pollution density of outflow in the parking lot is high. But it remarkably reduced when the outflow in the parking lot passed the rainwater management facility. The case of COD reduced averagely 50%, and SS reduced about 60%.

According to analysis of the rainfall pattern during June and July, it has 38 rainy days. The rainy day with below 10mm is about 22 days and over 100mm is merely 3 days. It would be enough to be efficient to operate the rainwater management facility for 22 days(36%) with below 10mm, although it is rainy season. In Korea, rainy day a year is about 100 days and day with below 10mm of them is about 75 days. In case of rainy day with below 10mm, the runoff is zero. Consequently, pollution loads by the first flush is able to control perfectly. The annual average rainfall is 1,300mm in Korea, the half of the annual average rainfall is concentrated in summer season and 75% of others is included rainfall with below 10mm. Considering the rainfall pattern in Korea, it is necessary to decrease the runoff and reduce the non-point pollution source by applying an decentralized rainwater management facility.

Now the rainwater management facility referred to municipal law, but it did not present precise installation regulation and specification. So in this study, we analyzed the effect by application and monitoring of facility. As a result, it showed the effect of sufficient runoff reduction and the control effect of non-point pollution source when it is applied to complexes. Now an application of the rainwater management facility is individually going on. Also it needs to present the application guidelines of the rainwater management facility in apartment complexes after analyzing the effect through the application of the rainwater management facility in whole complexes.

References

Moo-young, Han. Il-yong, Lee. Sang-cheol, Park. 2003. *The Effect of Rooftop on the Water Quality of Roof Runoff*. Journal of the Korean Society Water and Wastewater. vol.17(3).

Kyung-hak, Hyun. Jong-bae, Park. Sung-yong, Kim. Kyung-young, Jeong. Sun-young, Jang. Sung-sick, Ahn. 2005. *Rainwater Management Facility Cases in Korean Apartment Complexes*. 31th IAHR Congress.

Kyung-hak, Hyun. Sung-sick, Ahn. Jung-joo, Choi. Kyung-young, Jeong. Sung-yong, Kim. Jong-bae, Park. 2006. *The application Effect of Decentralized Rainwater Management Facilities in Apartment Complex*. HUAR vol.90.

Jurgen Foster. 1996. *Patterns of roof runoff contamination and their potential implications on practice and regulation of treatment and local infiltration*. Water Science and Technology. vol.33(6).

KWWA. 2005. *The Sewer Standards in Korea*.
Ministry of Government Legislation. 2006. *The Water Law in Korea*.
NIDP. 2003. *The improvement of Disaster Reduction Techniques by Pilot Basin and Storage & Infiltration Facilities Management.*
Tae-goo, Lee. Young-hae, Han. 2003. *An Analysis of Concept and Application of the Decentralized Storm Water Management in Korea.* KPI vol.38(5).