

Application of the Rainwater-harvesting System to an Ecological Housing Complex

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ABSTRACT : An eco-village was recently established in Seocheon-gun, Chungcheongnam-do as a part of the garden village promotion business. However, it is thought that the increase in development-caused impermeable surfaces may interfere with the efforts to secure water sources from the surrounding streamlets or maintaining waterways. This study aimed to overcome these problems by applying a rainwater-harvesting system to an ecological housing complex.

In this study, rainwater was designed to be used for flushing toilets in restrooms, gardening, or car washing, which resulted in a reduction in the consumption of water and in its outflow. This plan promises an 85% reduction effect in rainwater outflow from rooftops, a 50-ton annual water supply substitution effect per household, and a 1,800-ton water-saving effect per complex.

Keywords: Ecological housing complex, rainwater-harvesting system, rainwater management

1. INTRODUCTION

1.1 Background and Necessity of the Study

It is an undisputed fact that the high architectural density in urban areas and the rapid changes in land use have damaged the natural water circulation therein. As this environmental problem becomes a controversial issue, legislation regarding the securing of alternative water resources and the use of water by circulating it for efficient water management is being prepared.

The rainwater-harvesting system is currently being applied to a variety of buildings. To widen the scope, though, of the use of the rainwater-harvesting system and to commercialize it, its results must be monitored,

and the system must be implemented and improved. In this study, a technology of the rainwater-harvesting system was developed and analyzed. Accordingly, these researchers aim to successfully establish an ecological housing complex by applying and planning the theoretical aspects of the eco-village that have been researched on at home.

1.2 Purpose and Content of the Study

The results of this study will be applied to the plan for the eco-village located in Seocheon-gun. The main contents of this study are as follows:

First of all, the components of the rainwater-harvesting system were selected, and the capacity of the rainwater storage tank was

calculated.

Second, based on the analysis of the status of the target land, the plan to designate a space for the rainwater-harvesting system was established.

Third, the expected environmental and economic effects of the application of the rainwater-harvesting system were analyzed.

2. CONSTITUTION AND EFFECT OF THE RAINWATER HARVESTING SYSTEM

2.1 Constitution of the Rainwater-harvesting System

The following are the characteristics of the components of the rainwater-harvesting system that was applied to Seochon Eco-Village.

① The Rainwater-Using Tank

The rainwater-using tank is a round-shaped pillar made from PE materials. Once the quantity of the collected water is decided, it can be installed whether in the single or the composite shape.

② The Settling Tank

It is a round-shaped pillar with a diameter of 0.5 m and a height of 1 m. The rainwater flows into the induction pipe, and sediments pile up on the bottom. Then, the rainwater is sent to the rainwater tank through the screen. The sediments inside the settling tank should be removed at least more than two times a year.

③ The Pump and the Induction Pipe

This pump is used to make the rainwater flow into the induction pipe. A bladder should be attached to the induction pipe so that its inlet can rise over the water level.

④ The Filter and Trap

These facilities prevent sewage from flowing backward, and small animals like rats from coming in.

⑤ The Control Box

This box is designed to control the functions for the management of the rainwater-harvesting system, so that the stability of the

supply can be secured. The pumps, the water supply system, the gauge for measuring the quantity of the rainwater used, and the gauge for measuring the automatic water level are built in the control box, as an integral control function.

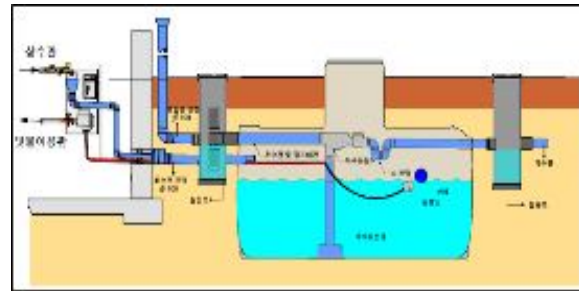


Figure 1: Mimetic diagram of the rainwater-harvesting system.

2.2 Water Quantity of the Rain-harvesting System

Based on the results of the monitoring of the rainwater-harvesting system that was applied to the detached house (Lee et al., 2007), the change in water quantity after rainfall is as follows:

The surface for water collection is 85 m², and two 5-ton rainwater tanks were installed so that a four-member family could use that water collected from such tanks as water supply in the restroom, for washing cars and landscaping. The results of the operation of the rainwater-harvesting system starting April 10, 2006 are as follows:

As seen in Fig. 2, the amount of rainfall in July 2006 was approximately 1,000 mm. After that time, until the middle of August, the rainfall decreased and the water level in the tank was gradually lowered. On October 22, 20-mm rainfall occurred and 5-ton rainwater was again collected.

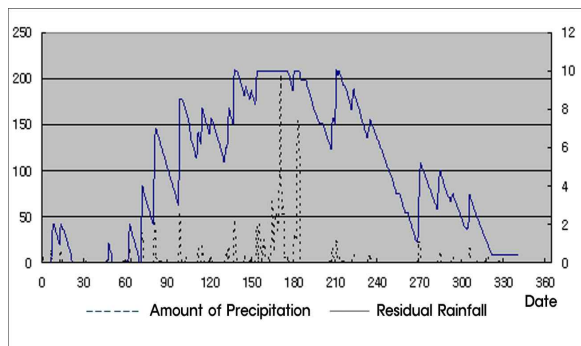


Figure 2. The changes in the quantity of the water in the rainwater tank according to its use in a detached house (2006.4-2006.12).

According to the analysis of the rainwater quantity that was used in a detached house, a total of 83 ton was used from April 10, 2006 to December 30, 2006.

More than 90% of the rainwater was used for the restroom, for washing cars or landscaping.

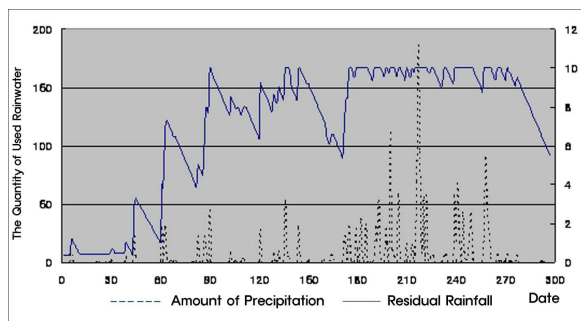


Figure 3. The changes in the quantity of Water in the rainwater tank according to its use in a detached house (2007.1-2007.10).

Fig. 3 shows the results of the analysis of the changes in the amount of rainfall and the use of rainwater in the tank from January 2007 to October 2007. As seen in the figure, the rainwater was at the full level from June to September.

The results of the analysis show that during this period, rainwater was used not only from December 25, 2006 to January 25, 2007. Based on the results above, if a 10-ton rainwater-harvesting system will be installed in a

detached house, it can be operated for 11 months a year. In conclusion, based on the results of the analysis, a four-member family used 2,44l ton rainwater for their restroom and landscaping.

2.3 Quality of the Water in the Rainwater-harvesting System

According to the research conducted by Lee et al. (2007), the results of the measurement of the water quality in the rainwater-harvesting tank are suitable as standards of recycled-water quality. At present, water standards in terms of the use of rainwater have not been set forth in Korea. The quality standards for recycled water are stipulated, though (Table 1). The results are as follows:

Five items (water temperature, external appearance, turbidity, PH, and smell) were analyzed. As a result, the temperature of the water was similar to that of groundwater. In addition, with respect to turbidity, there was a slight difference depending on whether rainfall occurred before the water quality was measured, but the said turbidity did not exceed 5 degree. These are therefore suitable as quality standards for recycled water.

PH also showed a neutral value and smell of settling tank (S.T) rainwater were rotten and smelled bad, but the rainwater inside the tank (R.T) had no smell.

Likewise, based on the results of the measurement of the quality of the water in the rainwater-harvesting system in the field, there is no problem with applying it to the field.

Table 1. Results of the Measurement of the Quality of the Water in the Rainwater-harvesting System

	2006.9.30		2007.6.30	
	S. T.	R.T.	S.T.	R.T.
Water Temp(°C)	22.2	21.3	21.5	20.9
Surface	not unpleasant	not unpleasant	not unpleasant	not unpleasant
Turbidity	5.69	4.52	3.44	2.36

(mg/L)				
pH	7.4	7.02	7.63	7.55
Smell	a little	No	No	No

3. Plan of the Rural Ecological Community in Seochon-gun regarding the Use of the Rainwater-harvesting System

3.1 Analysis of the Status, Direction, and Establishment of the Plan

The building area that was used as a catchment surface for the rainwater-harvesting system is 10,452 m² wide. Approximately 35% of the total area (29,749 m²) is used as a catchment surface. The houses are concatenated, and 36 households form a cluster-shaped housing group by 10~16 units. Housing and rest facilities are located in each housing group. Thirty-six households are being planned, and the desired population is 94 persons.

The planned quantity of the rainwater supply is 30 ton and 19.5 ton was set for this complex, and 10.5 ton for the common facilities. Likewise, as approximately 35% of the water is supplied to a common region by village, it is desirable to use the rainwater for public purposes or chores.

The rainwater-harvesting system was used to minimize the increasing quantity of the outflow after the development and to reduce the quantity of the supplied water used or consumed in each household. Another plan for naturally discharging the rainwater overflowing from the roof to small brooks or ponds is also being formulated.

3.2 Calculation of the Rainwater-harvesting System's Quantity

The capacity of the rainwater-harvesting tank should be calculated in consideration of the quantities of the collected and used rainwater for each household.

① Quantity of the Collected Rainwater

The quantity of the collected rainwater is obtained when the rainwater that falls onto each residing line is collected using the average rainfall per month.

$$E_R = 10^{-3} \times A_A \times e \times h_N \times \eta \quad \text{Equation (1)}$$

E_R : quantity of collected rainwater (m³); A_A : area of collected water (m²); e : ratio of collected water (%); h_N : amount of precipitation (mm); η : numeric filter efficiency (0.9)

In this case, the average catchment area reaches 219.4 m². The ratio of the collected water (e) differs but in this case, the residing line is covered with the slope roof. Therefore, 0.8 was applied.

For the amount of precipitation (h_N), the average rainfall data per month was used. The numeric filter efficiency (η) is the filter efficiency in the induction pipe of the reservoir. If the management is regularly carried out, the value generally reaches 0.9 or so.

② Quantity of Rainwater Used

Regarding the uses of tap water in households, the total amount of water, which could be replaced with rainwater, is assumed as the quantity of rainwater that is used. The quantity of rainwater that is used (P_b) is equivalent to the quantity of tap for restrooms, cleaning, and irrigation purposes, so 80 ℓ was applied.

$$BW_a = P_b \times n \times 30 \quad \text{Equation (2)}$$

BW_a : quantity of rainwater used; P_b : quantity of tap water used and replaced with rainwater per person; n : number of persons

Table 2. Daily Quantity of Tap Water Used by the Households in Seoul (Liter, %)

n: The number of Persons	
Total Quantity of Water Used	Quantity of Water Used by Purpose (ℓ)

Quantity Required of Total Rainwater	For Rest Rooms	For Laundry	For Washing the Face / Shower	For Drinking / Cooking	For Cleaning / Irrigation
233.3	263. (31.7 %)	47.0 (20.1 %)	61.1 (26.2%)	45.1 (19.3%)	16.9 (7.2%)

Source: The Ministry of Environment (2003), *Statistics for Tap Water 2001*.

As for the number of persons, 2.6 persons by household was applied, and for the monthly quantity of rainwater used per household, approximately 62,40ℓ/month was calculated.

③ Capacity of the Rainwater Tank

As two household-concatenated types were applied, 124,80ℓ/month was spent in two households per line. The monthly average quantity of the rainwater that can be collected from each line can be seen in the following table:

Table 3. Average Catchment and Rainwater Used per Month

	Average Rainfall (hN, mm)	Average Catchment (ER, m ³)	Shortage/Residual (m ³)
Jan.	27.2	4.3	-9
Feb.	33.3	5.3	-8
Mar.	55.7	8.8	-4
April	93.6	14.8	2
May	101.4	16.0	3
Jun.	168.9	26.7	14
Jul.	287.5	45.4	32
Aug.	279.8	44.2	31
Sep.	140.3	22.2	9
Oct.	60.8	9.6	-3
Nov.	56.1	8.9	-4
Dec.	29.6	4.7	-8

If we assume the capacity of the rainwater-harvesting tank to be 13 ton, as the quantity of the collected rainwater reaches a lower level in January~March compared to the quantity of

rainwater that will be used or is needed, tap water should augment the rainwater supply as follows. As there is much more rainfall, however, in April~September compared with the other months, part of the 13-ton rainwater in the tank is sent to infiltration or undercurrent facilities. To address the shortage in October and November, as the rainwater flowing through an undercurrent stored in September can be used, rainwater can be used for restrooms, for cleaning, and for irrigation purposes in April ~ November.

If a 13-ton rainwater tank will be installed in each line, it will function as a rainwater undercurrent facility that will deal with approximately 230 ton of rainwater every month.

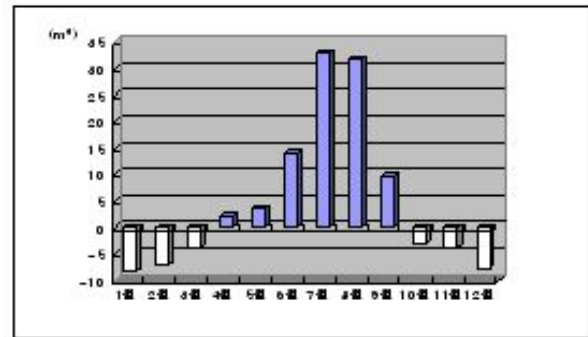


Figure 4. The monthly outflow quantities and tap-water-complementing quantity.

4. The Basic Plan for the Rainwater-harvesting System in site

4.1 Plan for Placement

Based on the calculated capacity of the rainwater-harvesting tank and the conditions of the target land, the following basic plan was formulated:

- ① The collected rainwater shall be used for restrooms and gardens, and for the irrigation of lands devoted to farming crops(Fig5.).
- ② The overflow from the storage tank must be discharged into the streams and ponds inside the complex.
- ③ The location of the storage tank must be

such that the overflowing rainwater can freely fall from the said tank considering the geographic slope(Fig6.).

④ The storage tank must be close to streams or ponds so that the length of the conduit can be shortened. Considering the items above, the plan was formulated as seen in Fig. 7.

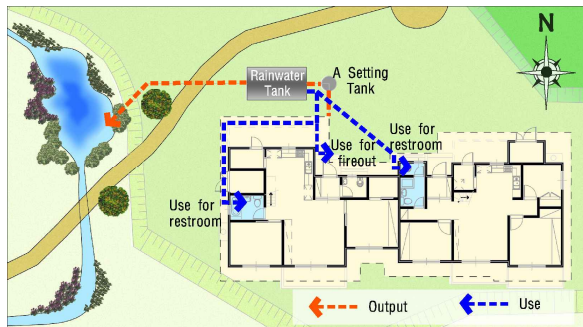


Figure 5. Map of rainwater flowing into an individual building.

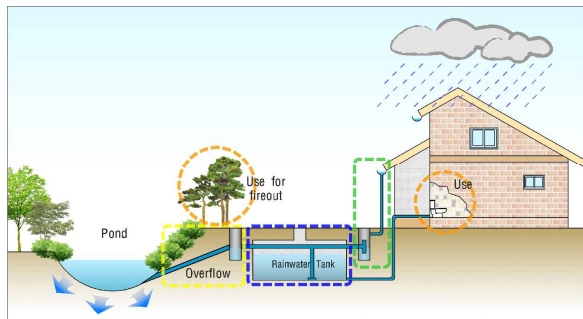


Figure 6. The rain-harvesting system for the use of rainwater in a detached house.

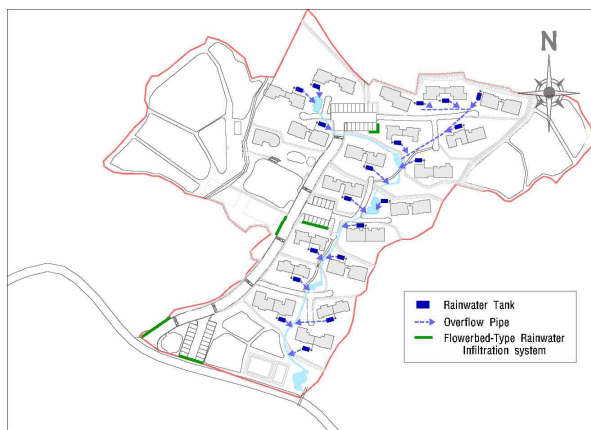


Figure 7. Scheme plan for the rainwater-harvesting facility.

4.2 Expected Effect of the Study

First, the use of the rainwater-harvesting system is expected to reduce the quantity of the outflowing rainwater. If each line installs a 13-ton rainwater storage tank, it is expected to under-retain 179 ton rainwater considering the outflow reduction due to the use of rainwater and the quantity of the rainwater that is under-retained, and it is expected to collect 3,222 ton rainwater. This can reduce the total quantity of rainwater outflowing from the roof's surface every year to 85%.

Second, the use of the rainwater-harvesting system is expected to reduce the water supply. If a 2.4-person household uses 6,240ℓ/month of rainwater, the quantity of rainwater will reach 49,920ℓ in April~November. In other words, the quantity of tap water that can be replaced with rainwater will reach 50 ton. Due to the use of rainwater, a total of 1,800 ton of tap water can be saved. If the quantity of tap water used reaches 1-20 ton and the price of tap water (for households) is 360 won, 650,000 won can be saved, and if more than 31 ton tap water is used at 790 won/m³, the tap water tax is expected to be reduced by 1,400,000 won.

Third, the sewerage tax can be reduced if rainwater will be used. If the sewage in the eup, myeon, and dong regions reaches 1~20 ton, the tax will be 90 won/m³, and if it goes beyond 31 ton, the tax will be 205 won. Thus, the sewage charge can be reduced from approximately 160,000 won to 370,000 won.

As seen above, through this study, Economic and environmental effects could also be expected.

5. CONCLUSION

Recently, as part of the plan to develop a region, a local autonomous entity and the civilians in the region tend to cooperatively

plan the rural community. In particular, a rural ecological community is being planned and promoted in Seocheon-gun, Chungcheongnam-do based on an ecological theme.

This study was conducted to explore the possible reduction of the water supply and runoff using rainwater that is suitable for development purposes. Towards this end, the plan regarding the application of the rainwater-harvesting system was formulated.

From now on, the rain-harvesting system will be more actively used for securing water resources and for preventing or arresting disasters. In addition, the Ministry of Environment and the Ministry of Land, Transport, and Maritime Affairs are preparing for related legislation. Thus, this study is expected to provide assistance to self-governments or private developing corporations by analyzing and suggesting the composition of the rainwater-harvesting system that can be supplied to houses, the method that can be used to calculate the capacity of the rainwater storage tank, the plan regarding the space to be used for such purpose as ecological development, and the expected effect of the system's utilization.

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