International Journal of Control and Automation
Vol.8, No.12 (2015), pp.77-88
http://dx.doi.org/10.14257/ijca.2015.8.12.07

Analysis on the Performance Evaluation of a High-Speed Filtering Apparatus for the Treatment of Combined Sewer Overflows (CSOs)

Sangleen Yun[1a], Seogku Kim[1b] and Hyundong Lee[1, 2c]

[1]Korea Institute of Civil Engineering and Building Technology, Environmental and Plant Engineering Research Institute 283 Goyangdae-ro, Ilsanseo-gu, Goyang-si, Gyeonggi-do, Republic of Korea
[2]University of Science and Technology, Construction and Environment Engineering 217, Gajeong-ro, Yuseong-gu, Daejeon, Republic of Korea
[a]leen70@kict.re.kr, [b]sgkim@kict.re.kr, [c]hdlee@kict.re.kr

Abstract

In this study, the generation characteristics of the Combined Sewer Overflows (CSOs) that occur in urban areas were investigated. In addition, performance evaluation of the CSO treatment efficiency was conducted through the field application of a high-speed filtering apparatus using a fibrous filter medium for the treatment of the CSOs that occurred in an urban area. The study site, a city located in Seoul, South Korea, was one that included the typical residential and commercial districts. The daily average flow rate of the Eungbong drainage area, which was the study site, was 92.5 m^3/hr during the dry season, and the daily average flow rate ranged from 70.2 to 129.2 m^3/hr, indicating a wide daily-average-flow-rate range. The highest flow rate was shown at around 9 a.m. on weekdays and at around 11 a.m. on weekends. The average influent concentrations that occurred during the dry season were 19.0 mg/L (BOD), 15.9 mg/L (COD), 10.9 mg/L (SS), 33.9 mg/L (TN), and 0.5mg/L (TP), and the hourly concentration ranges turned out to be 4.1~43.5 mg/L (BOD), 9.5~26.8 mg/L (COD), 3.6~33.0 mg/L (SS), 25.5~52.2 mg/L (TN), and 0.4~0.9 mg/L (TP).

The results of the field application of a high-speed filtering apparatus using a fibrous filter medium showed that the average treatment efficiency of SS was 63.7% during the dry season. The average treatment efficiency of SS during rainfall was 84.2% (1^{st}), 88.0% (2^{nd}), 87.5% (3^{rd}), 85.8% (4^{th}), 75.8% (5^{th}), 75.5% (6^{th}), and 90.3% (7^{th}), and exhibiting more than 80% treatment efficiency. In the case of organic contaminants like BOD, however, low treatment efficiency (less than 30%) appeared. Judging from the above results, it is difficult to expect a treatment effect if the influent concentration is less than 30 mg/L in the case of an organic material when the high-speed filtering apparatus is applied to the site, and even in the case of an influent concentration of more than 30 mg/L, the treatment efficiency is about 30% on average. The treatment effect of the particulate material (SS) remained quite high, however, without significant restrictions on the filtering liner velocity and influent concentration. The results of the analysis of the characteristics of the CSOs in urban areas and of the application of a high-speed filtering apparatus using a fibrous filter medium are expected to be utilized as basic data for management alternatives to reduce rainfall runoff loads with respect to overflows that occur during rainfall.

Keywords: *Combined Sewer Overflows (CSOs), Fibrous Filter Medium, Runoff First Flush, High-Speed Filtering Apparatus*

ISSN: 2005-4297 IJCA

1. Introduction

Combined sewer systems in urban areas were constructed so that a single tube can perform two functions. The first function is as a sewer that collects household sewage and industrial and commercial wastewater, and carries them to the sewage treatment plant, and the second function is as a rainwater pipeline that prevents inundation by excluding the surface runoff occurring in the drainage area during rainfall and discharging it to the receiving body of water [1]. The combined sewer overflows (CSOs) are the flow quantities that exceed the capacity of the intercepting sewer while performing a rainwater exclusion function, and that are discharged to the receiving body of water through an overflow adjustment facility. The runoff water that occurs during the initial rainfall is discharged by moving the non-point pollution source to the sewer. Especially in the case of combined sewers, the addition of sewage and rainfall runoff leads to a flow rate increase in the sewer and to the inclusion of high-concentration pollutants. In general, the intercepting sewer is designed to intercept at least two to three times, and as much as five times the sewage that occurs in the drainage basin during the dry season. CSOs can occur, however, in the case of the malfunction of the adjustment facility or during the dry season, when the discharge capacity of the intercepting sewer is inadequate [2]. In rainfall runoff, the ground surface water containing various pollutants, such as organic and inorganic materials, heavy metals, and aromatic organic compounds, and the contaminants in the rainwater collection unit and gutter, are included, and the sewer sediments due to the flow rate increase within the sewer are discharged after being re-floated. In the CSOs, multiple contaminants containing hazardous substances, such as organic matter, bacteria, oil compounds, and heavy metals, are included, and they exhibit the characteristic of being discharged temporarily at the time of rainfall [3]. In particular, as the initial rainfall runoff that occurs in the early stage of rainfall shows a pollution level up to dozens of times that of the sewage during the dry season due to the first flush of the ground surface and the re-floating of the sediments within the sewer, its effects on the receiving body of water have been reported to be significant [4].

The degree of water pollution caused by the water pollutants discharged during rainfall gradually increases with the increasing flow rate [5], and the water pollutants respond to rainfall very sensitively [6,7]. In addition, rainfall runoff has a characteristic of increasing the degree of water pollution due to the initial rainfall [8], and the discharged water pollutants are reported to vary depending on the regional and temporal characteristics. In the case of Japan, with regard to the mean water quality, the water quality fluctuations during the dry season were within a two- to threefold range, whereas those during rainfall turned out to be up to 10 times. Even in the United States, there was a great difference in water quality fluctuations during rainfall. According to the USEPA report, CSOs contain all the contaminants, such as organic matter, bacteria, nutrients, ammonia, turbidity, TSS, and toxic substances other than acidic wastewater. A huge amount of these pollutants are discharged through the overflow outlet in a short time, adding to the water body contamination [9]. If CSOs are introduced into rivers and lakes, the proper water quality standards cannot be maintained, causing environmental pollution.

At present, South Korea is greatly expanding its facilities for treating non-point pollution sources in the city sewage treatment and industrial waste treatment plants, but the water quality of the rivers and lakes has not yet been improved. One of the reasons for this is that a great volume of non-point pollutants other than the point pollution sources are flowing into the rivers and lakes. The effects of the non-point pollution source loads discharged during rainfall on the water quality are greater as the sewage treatment ratio is improved, and as the level of economic activity increases. In South Korea, where there is high-density land use, more than 50% of the water pollution loads caused by suspended solids, and more than 80% of the nutrients in the case of closed waters, are due to non-point pollution sources. The methods for controlling CSOs include such fundamental pollution source control measures such as source control and replacement with separated sewer pipes. These methods cannot be used in the developed urban areas, however, due to their high cost and high density, or because they require a long period of time. In this case, it is necessary to purify contaminated water through apparatus-type facilities that can treat the CSOs, and to discharge the purified water to the public water system.

This study was designed to investigate the characteristics of the CSOs that occur in urban areas, and to promote the field application of the high-speed filtering apparatus for the treatment of overflows occurring in the study site. The results of the analysis of the characteristics and application of the treatment system are expected to be utilized as basic data for management alternatives to reduce rainfall runoff loads.

2. Material and Methods

2.1. Study Site

The old downtown in Seoul, South Korea was selected as the study site. The study site has the characteristic of an old downtown, which has typical residential and commercial districts. The total catchment area of the basin was 568,275 m^2. The residential area was found to be 248,815 m^2, constituting about 43.8% of the total downtown area. The commercial area was 7,635 m^2; the industrial area, 62,564 m^2; the roads, 62,564 m^2; the green zone, 45,590 m^2; and the other areas, 196,159 m^2.

2.2. Fibrous Filter Medium

Unlike the effluent on the road surface, the rainfall runoff in the combined sewer has many organic substances and suspended matters, and as such, the selection of a filter medium is considered very important. The filter medium that was applied in this study for the treatment of CSOs was completed by cutting a mat made with uniform thickness through chemical and thermal treatment following the processing primarily of non-woven fabrics, and of their layering, after mixing and arranging fibers with different thicknesses. Figure 1 shows a SEM photograph taken in the x, y, z directions of the filter medium that was used in this study, which reveals that fine fiber layers were formed in the same direction. This filter medium was found to be smaller than other media made with a single material, such as Polypropylene (PP or PETE), and boasts higher pollutant removal efficiency. Table 1 shows the characteristics of the fibrous filter medium.

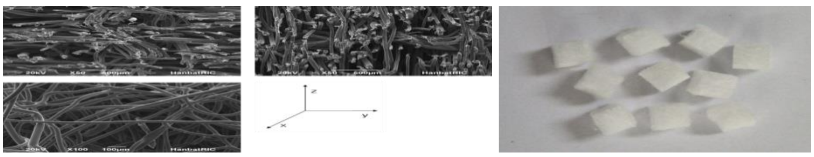

Figure 1. Fibrous Filter Medium

Table 1. Characteristics of Fibrous Filter Medium

Item	Characteristics
Size and shape	5*3mm(thickness)
Material	Polypropylene (PP)
Diameter (㎛)	10-100
Porosity (%)	90-94%
Specific surface area (m^2/m^3)	8000

2.3. High-Speed Filtering Apparatus for CSOS Treatment

The high-speed filtering apparatus for CSO treatment (EcoTreat) is designed to carry the overflows occurring in the early stage to the sewage treatment plant through the intercepting sewer, to treat them up to an advanced or highly advanced level, and to discharge them to the public water system. Moreover, it is a technology that can treat to capacity or up to more than a certain level the CSOs that occur above a certain flow rate, with only a small number of facilities.

The apparatus is composed of an inlet, an outlet, and a filtration unit. In the outlet and the filtration unit, there is a non-powered discharge regulator (NPDR) for flow rate control and backwashing. The inlet allows sewage to be introduced without delay into the intercepting pipe during the dry season, through the inflow and runoff channels at the bottom of the treatment facilities. The outlet has an NPDR installed in it to block the sewage inflow into the intercepting sewer when the water level rises after the beginning of rainfall. The NPDR is designed and devised to prevent clogging of the orifice due to impurities by securing the cross-sectional area of the inlet as much as possible at ordinary times, and to automatically be blocked in response to the rise in the water level of the combined sewer during the rainfall, so as to prevent low-concentration sewage from entering the intercepting sewer and to induce it to go to the filtration unit. Meshes were installed at the top and bottom of the filtration unit to prevent the outflow of the filter medium, and low-concentration sewage was treated by charging a three-dimensional fibrous filter medium (Figure 2).

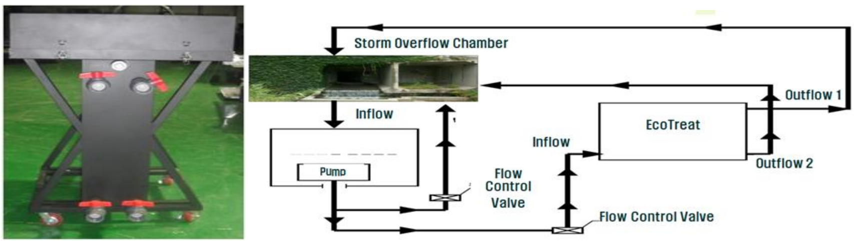

Figure 2. Schematics of Field Application

2.4. Monitoring Methods

As for the instrument for monitoring the flow rate, a portable ultrasonic flow meter was used, and manual and auto-samplers were used for water quality sampling during the dry season and during rainfall. An overview of the flow rate and water quality monitoring is shown in Table 2.

Table 2. Overview of the Flow Rate And Water Quality Monitoring

Segment	Content
Flow rate survey	·Monitoring period: June 12-October 29 (in summer) ·Data storage period: 5 minutes ·Measuring instrument maintenance cycle: 7-10 days/ time
Water quality survey	·Survey items: BOD, COD, SS ·Number of surveys: 1 time during the dry season, 4 times during rainfall ·Sampling frequency - During the dry season: Every hour × 24 pieces/time - During rainfall : After occurrence of CSOs (within 1 hour): Sampling conducted ever minutes : 1 hour after occurrence of CSOs: Sampling conducted at 20- to 60-minute intervals - Need to adjust the sampling interval actively on the site so that the first-flush effect during rainfall can be seen
Water quality analysis	·Water quality samples were taken from the location that could represent the characteristics of the point. · The samples taken from the site were stored in the ice box before they were sent to the analysis agency. ·Korea Environmental Preservation Association was commissioned to conduct water quality analysis to increase the reliability of the analysis results.

To examine the characteristics of the CSOs in the study site through flow and water quality monitoring, measuring instruments were installed and operated from May to October in summer.

3. Results and Discussion

3.1. Characteristics of the CSOS in the Study Site through Onsite Monitoring

3.1.1. Analysis of the Flow Rate and Water Quality Patterns during the Dry Season: As for the flow patterns of the runoff generated during the dry season, the hourly flow patterns were analyzed using the flow data during the dry season of the day with more than three preceding dry days, considering the impact of the preceding dry season. In addition, the flow patterns were classified separately to determine the impact of the weekday and weekend flow pattern fluctuations. During the around-five-month monitoring period, the total flow data that were used in the flow pattern corresponded to 25 days. The pattern analysis results are shown in Figure 3.

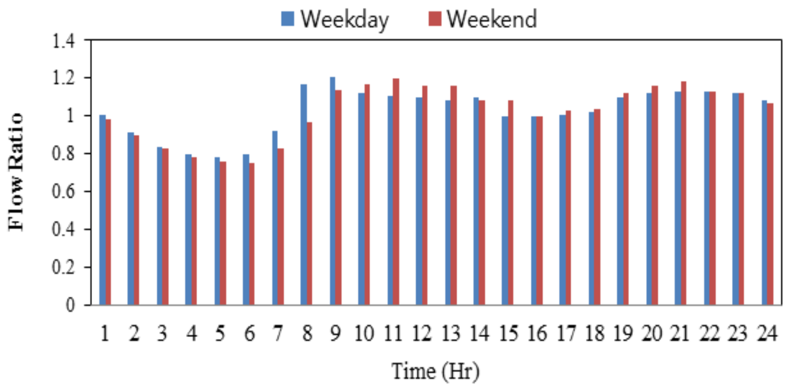

Figure 3. Changes in the Flow Pattern during the Dry Season (Study Site)

In the case of the dry season, the total daily average flow rate was 92.5 m^3/hr, and the daily average flow rate ranged from 70.2 to 129.2 m^3/hr, showing a slightly larger range width. The highest flow rate was found at around 9 a.m. on weekdays and at around 11 a.m. on weekends. With regard to the hourly flow rate, the total flow rate ranged from 0.76 to 1.18 on weekdays (0.78-1.20) and on weekends (0.73-1.19), showing similar flow rates. The flow rate fluctuation showed a constant tendency without showing a large variation, except for the early morning hours (6 -8 a.m.). In the case of this survey point, the hourly flow rate fluctuation was found to be relatively small compared to the flow pattern in urban areas, where the flow rate decreases rapidly at sundown and significantly increases from 6 to 8 a.m. and from 7 to 10 p.m.

Figure 4 shows the hourly concentrations of the contaminants in the study site during the dry season. The average concentrations during the dry season were 19.0 mg/L (Biochemical Oxygen Demand, BOD), 15.9 mg/L (Chemical Oxygen Demand, COD), 10.9 mg/L (Suspended solids, SS), 33.9 mg/L, and the hourly concentration ranges were 4.1- 43.5 mg/L (BOD), 9.5-26.8 mg/L (COD), 3.6-33.0 mg/L (SS). In the case of SS, BOD, and COD, higher concentrations were shown between 8 and 11 a.m. than at other times. Total Nitrogen (TN) showed a variety of changes in its hourly concentration values, without a constant trend. In the case of Total Phosphorus (TP), the hourly concentration variation was on the whole constant.

In the case of this survey point, the concentration of contaminants was found to be low compared to the concentration range of the sewage generated from the downtown area. This is because the concentration of contaminants was low and the hourly flow rate fluctuation was small due to the small number of preceding non-rainfall days (two days) and to the influence of the contaminated water from unidentified sources introduced continuously from the outside.

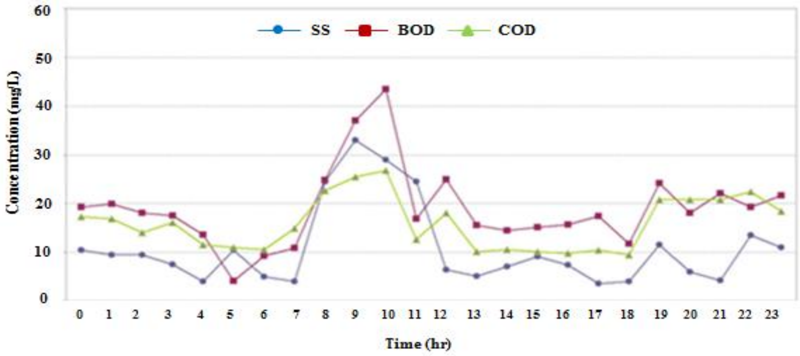

Figure 4. Changes in the Hourly Water Quality Patterns during the Dry Season

3.1.2. Analysis of the Flow Rate and Water Quality during Rainfall: CSO monitoring during rainfall was conducted for four times (June 12, June 26, July 16, and October 2) in summer. Table 3 shows an overview of the field survey of CSO monitoring during rainfall.

Table 2. Overview of Rainfall Field Monitoring

Segment	12 June	26 June	16 July	2 October 2
Preceding non-rainfall period (day)	17	11	11	4
Daily rainfall (mm)	27.0	3.5	50	21
Rainfall duration	5'50"	30"	12'10"	12' 20"
Average rainfall intensity (mm/hr)	4.6	7.0	4.1	1.7
Return period (month)	0.26	0.27	0.28	0.18

Figure 5 shows the flow rate and water quality patterns generated during rainfall. The first monitoring confirmed that the water quality suddenly became turbid about 20 minutes from the occurrence of surface runoff. In the case of the study area, the first-flush effect (SS concentration: 1,305 mg/L) occurred at 0.5-1 mm rainfall, and the SS concentration increased up to 1,057 mg/L with the increase in rainfall (1.5 mm) about 30 minutes after the restoration of the water quality following the initial flush effect. It was determined that in the case of the Eungbong drainage area, where the proportion of the impermeable layer is high and the slop is large, there was a tendency for the flow rate to increase rapidly due to the small concentration even at less rainfall.

In the second monitoring, the first-flush effect occurred about 10 minutes after the initial rainfall, due to the higher rainfall intensity from the beginning of rainfall compared with the first survey. During the second monitoring period, the maximum SS concentration was 1,723.3 mg/L, which is higher than that during the first monitoring period, and the water quality was restored to the concentration range during the dry season about 20 minutes after the occurrence of the maximum concentration.

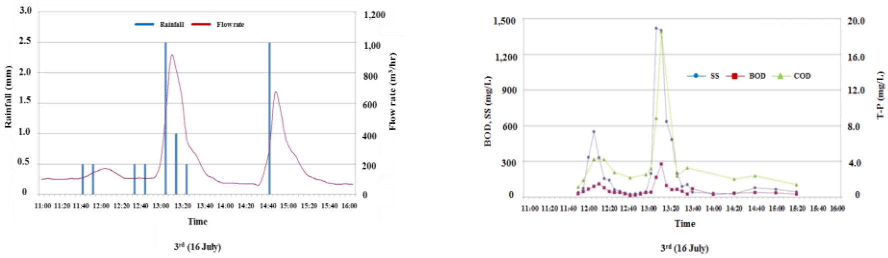

Figure 5. Changes in the Flow Rate and Water Quality during Rainfall

In the case of the third monitoring, the rainfall duration was 12 hours 10 minutes, but due to the intermittent rainfall, the flow rate increased and the water quality rapidly became turbid from about 1 hour 30 minutes after the initial rainfall. During the monitoring period, the maximum SS concentration was 1,418.5 mg/L, showing a range similar to those in the first and second field surveys.

In the fourth rainfall field survey, the first-flush effect occurred 6 hours 20 minutes after the first rainfall, due to the initial intermittent rainfall, and the water quality was restored to the concentration range during the dry season 30 minutes after the occurrence of the maximum concentration. The maximum SS concentration was 342.5 mg/L, which was significantly lower than the average maximum concentration of 1,482.2 mg/L during the first to third survey period. It was determined that the reason for this is that the first-flush effect was weakened due to the continuous rainfall (number of rainy days: 45) between the third field survey period (July 16) and the fourth field survey period (October 2).

3.2. Evaluation of the Field Application of the High-Speed Filtering Apparatus

The results of the four-time rainfall monitoring of the Eungbong distribution reservoir showed that the rainfall intensity was 1.7-7.0 mm/hr and that the rainfall duration was from 30 minutes to 12 hours 20 minutes. Due to the first-flush effect, the concentration was increased to the maximum between 10 and 20 minutes after the surface runoff caused by the initial rainfall, and the water quality was restored to the concentration range during the dry season 20-30 minutes from the occurrence of the maximum concentration.

Given the CSO characteristics of the site, an evaluation of the field application of a high-speed filtering apparatus by rainfall event was carried out with respect to the dry season and rainfall. In the case of rainfall, the evaluation was conducted by dividing it into that for short-term rainfall and that for long-term rainfall. Experiments were also conducted with a total of seven events: four times for short-term rainfall, with a range of 20-30 minutes; and three times for long-term rainfall, with a range of 70-80 minutes.

3.2.1. Analysis of the Flow Rate and Water Quality during Rainfall: The average filtering linear velocity set upon the dry season was 995 m/day, and the maximum head loss value at the end of the experiment was measured at 29 cm.

The average influent concentrations were 33.6 mg/L (BOD), 32 mg/L (COD), 23.5 mg/L (SS), 26.1 mg/L (TN), and 2.9 mg/L (TP), and the average treatment efficiency by influent turned out to be 26.4% (BOD), 19.6% (COD), 63.7% (SS), 9.9% (TN), and 7.2% (TP). In the case of SS, a particulate material, although the average influent concentration was 23.5 mg/L, which is very low, the treatment efficiency was more than 60% on average.

3.2.2. Changes in the Treatment Efficiency of the High-Speed Filtering Apparatus during Rainfall: Figure 6 shows the changes in the head loss and filtering linear velocity by short-term rainfall event according to the elapsed time in each off our experiments.

The average filtering linear velocity was 1,079 m/day for the first experiment, 1,073 m/day for the second, 1,264 m/day for the third, and 1,148 m/day for the fourth, all showing an influent flow rate of more than 1,000 m/day. During the four experiments, the fibrous filter medium was not replaced, and the maximum head loss value measured at the end of each experiment was 13.5cm for the first experiment, 41.5cm for the second, 36cm for the third and 10.5cm for the fourth.

It was generally considered that as the filtering linear velocity increases, the growth rate of the head loss with the passage of time becomes large in proportion to the filtering linear velocity. The results of the second and fourth experiments confirmed, however, that the growth rate of the head loss has a different tendency even at the filtering linear velocity with the same range. Therefore, in addition to the filtering linear velocity, the influent characteristics and the filter medium cleaning effects due to occasional backwashing were also determined to cause an increase in head loss with the passage of time.

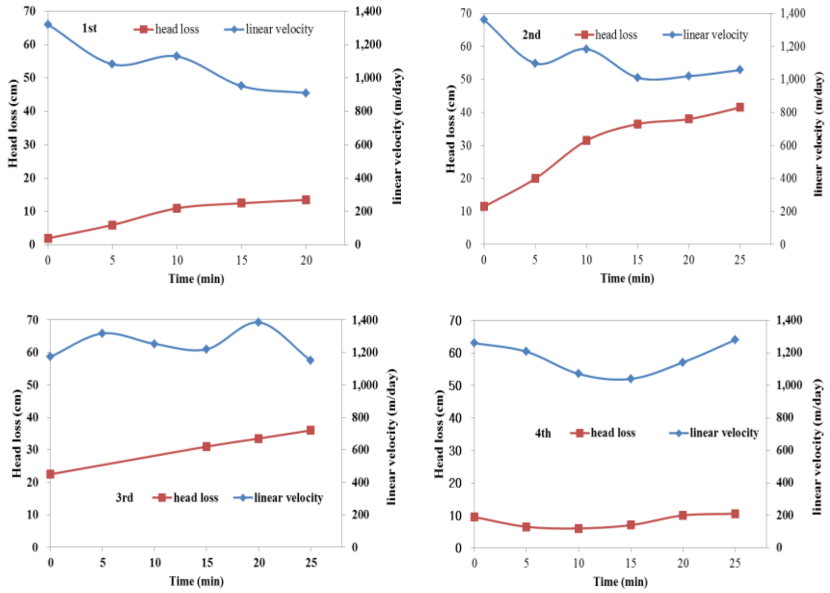

Figure 6. Changes in the Head Loss and Filtering Linear Velocity by Short-Term Rainfall Event

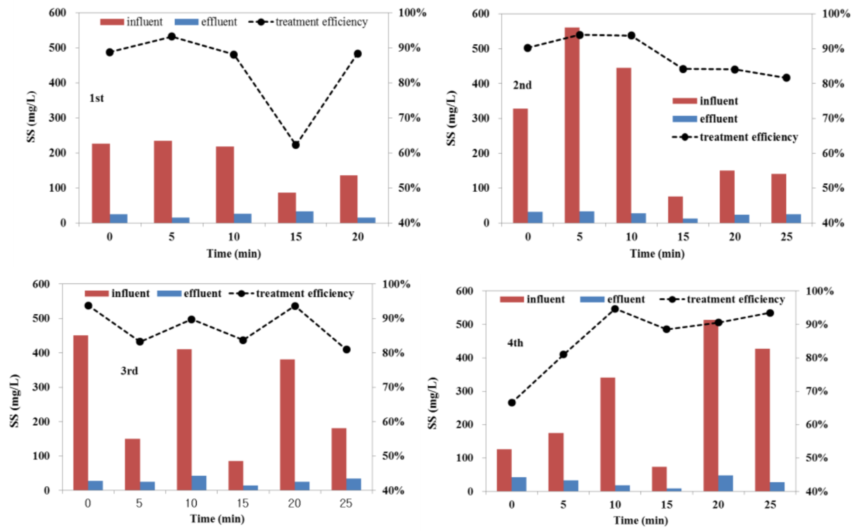

Figure 7. Experiment Results of Short-Term Rainfall Events (SS)

Figure 7 shows the treatment efficiency and the changes in the influent and effluent concentrations of SS by short-term rainfall event. The average influent concentration of SS was 180.6 mg/L in the first rainfall event, 283.7 mg/L in the second, 276.5 mg/L in the third, and 275.7 mg/L in the fourth, and the average effluent concentration turned out to be 23.1 mg/L in the first rainfall event, 25.8 mg/L in the second, 28.1 mg/L in the third, and 29.7 mg/L in the fourth.

The average treatment efficiency of SS was 84.2% in the first rainfall event, 88.0% in the second, 87.5% in the third, and 85.8% in the fourth, all showing more than 80% treatment efficiency. Although there was a great deviation in the influent concentration in each experiment, the effluent concentration was found to be less than 30 mg/L.

Given that the maximum concentration of SS increased up to more than 1,000 mg/L according to the rainfall field monitoring results, the SS treatment efficiency of the high-speed filtering apparatus is expected to be further enhanced in the case of a short-term rainfall with duration of less than one hour.

Figure 8 shows the changes in the head loss and filtering linear velocity by long-term rainfall event. The average filtering linear velocity was 1,007 m/day in the fifth experiment, 857 m/day in the sixth, and 741 m/day in the seventh. Each experiment was conducted by lowering the filtering linear velocity ranging from 700 to 1,000 m/day compared with the short-term rainfall simulation. The maximum value of the head loss measured at the end of each experiment was 42 cm for the fifth experiment, 33.5 cm for the sixth, and 37 cm for the seventh.

The long-term rainfall event had no significant difference from the short-term rainfall event in terms of the maximum value of the head loss and the growth rate with the passage of time

Figure 9 shows the treatment efficiency and the changes in the concentrations of SS by rainfall event (5^{th}~7^{th}). The average concentration of SS was 78.2mg/L in the fifth rainfall event, 175.5mg/L in the sixth, and 402.1mg/L in the seventh, and the average effluent concentration turned out to be 18.6mg/L in the fifth rainfall event, 35.8mg/L in the sixth, and 32.4mg/L in the seventh.

The average SS treatment efficiency was 75.8% in the fifth rainfall event, 75.5% in the sixth, and 90.3% in the sixth, showing high treatment efficiency (75-90%), similar to that in the short-term rainfall simulation. In particular, the average treatment efficiency was found to be more than 90% in the seventh experiment, with the average filtering linear velocity of 741 m/day.

The SS concentration of the backwash effluent by backwashing conducted immediately after each long-term rainfall simulation experiment was 2,582mg/L, about 10 times higher than that of the influent.

Judging from the above results, the treatment effects of particulate materials in the EcoTreat system is kept significantly high without great constraints on the filtering linear velocity and influent concentrations. In the case of organic materials, it is difficult to expect a treatment effect if the influent concentration is less than 30mg/L, and even in the case where the influent concentration is more than 30mg/L, the treatment efficiency is about 30% on average.

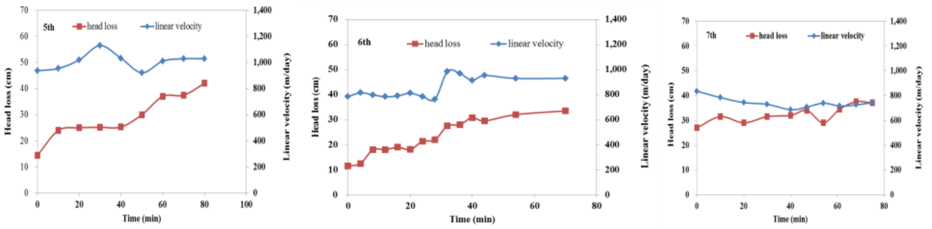

Figure 8. Changes in the Head Loss and Filtering Linear Velocity by Long-Term Rainfall Event

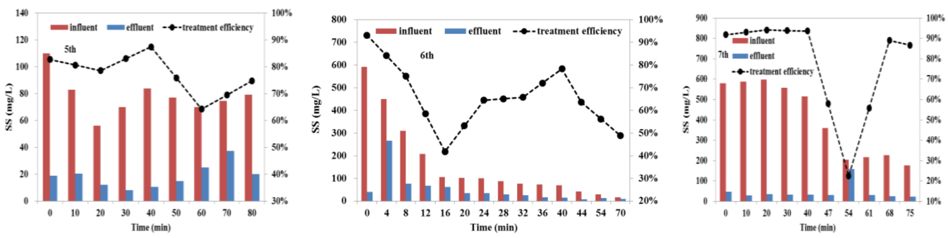

Figure 9. Experiment Results of Long-Term Rainfall Events (SS)

4. Conclusions

In this study, the generation characteristics of the combined sewer overflows (CSOs) that occur in urban areas were investigated. In addition, performance evaluation of the CSO treatment efficiency was conducted through the field application of a high-speed filtering apparatus using a fibrous filter medium for the treatment of the CSOs that occurred in an urban area.

1) The total daily average flow rate of the Eungbong drainage area, the study site, was 92.5 m^3/hr during the dry season, and the daily average flow rate ranged from 70.2 to 129.2 m^3/hr, indicating a wide daily-average-flow-rate range. The highest flow rate was shown at around 9 a.m. on weekdays and at around 11 a.m. on weekends.

2) The results of the monitoring of the rainfall event with the average rainfall intensity, which ranges from 1.7 to 7.0 mm/hr, showed that the concentration was increased by the first-flush effect to the maximum 10-20 minutes after the occurrence of surface runoff caused by the first rainfall, and it was confirmed that 20-30 minutes after the occurrence of the maximum concentration, the water quality was restored to the concentration range during the dry season. The inflow concentrations of the CSOs that occurred during rainfall turned out to be 17.9-192.5 mg/L (BOD) and 5.0-810.0 mg/L (SS).

3) The results of the field application of a high-speed filtering apparatus using a three-dimensional fibrous filter medium showed that the average treatment efficiency of SS was 63.7% during the dry season. The average treatment efficiency of SS during rainfall was 84.2% (1^{st}), 88.0% (2^{nd}), 87.5% (3^{rd}), 85.8% (4^{th}), 75.8% (5^{th}), 75.5% (6^{th}), and 90.3% (7^{th}), which indicates more than 80% treatment efficiency. In the case of organic contaminants such as BOD, however, low treatment efficiency (less than 30%) was shown.

The results of the field application of a high-speed filtering apparatus for the treatment of sewer overflows showed that it is difficult to expect a treatment effect if the influent concentration is less than 30 mg/L in the case of an organic material, and even in the case where the influent concentration is more than 30 mg/L, the treatment efficiency is only about 30% on average.

The treatment effects of particulate materials, however, turned out to be consistently significantly high, without huge constraints on the filtering linear velocity and influent concentrations. Gromarie-Merz et al. (1998) conducted a comparative analysis of the pollutant loads on the surface runoff and the sewer effluent at the tip of the drainage basin and deduced that in the case of surface runoff, the particulate fraction was 30-80% whereas the sewer effluent fraction was 70-90%, which is due to the effects of the erosion of the sediments during rainfall [10]. In this regard, it is concluded that among the overflows that occur during rainfall, the particulate contaminants can be blocked from being directly discharged into the rivers. In addition, it is expected that the findings of this study will be utilized as basic data for management alternatives to reduce the rainfall runoff loads of the overflows that occur in urban areas.

Acknowledgments

This research was financially supported by Korea Institute of Civil Engineering and Building Technology (KICT), project No. 2015-0178.

References

[1] EPA, “Combined sewer overflow control”, **(2002)**.
[2] B. J. Adams and F. Papa, “Urban Stormwater Management Planning with Analytical Probabilistic Models”, John Wiley and Sons, INC., **(2002)**.
[3] R. Field, M. L. O’Shea and k. k. Chin, “Integrated stormwater management”, LEWIS PUBLISHERS, **(1993)**.
[4] EPA, “Implementation and enforcement of the combined sewer overflow control policy”, **(2001)**.
[5] S.H. Jeong, K. P. Young and H. W. Chan, “Runoff characteristics of non-point source pollution in lower reaches of livestock area”, J. Kor. Soc. Environ. Eng., vol. 34, no. 8, **(2012)**, pp. 557-565.
[6] M.W. Lee and S.L. Young, “Study on runoff characteristics of non-point pollutant with rainfall intensity: A case of fowls manure”, J. Wetlands Soc., vol. 11, no. 1, **(2009)**, pp. 91-97.
[7] J.H. Ahn, S. L. Yun and S. K. Kim, “Runoff characteristics of non-point source according to cultivation activity in river district”, J. Kor. Soc. Environ. Eng., vol. 34, no. 7, **(2012)**, pp. 480-487.
[8] K. W. Bang, C. S. Choi, J. H. Lee and S. K. Choi, Investigation of runoff characteristics and estimation of unit pollutants load for first flush. J. Kor. Soc. Urban Environ., vol. 7, no. 1, **(2007)**, pp. 49~60.

[9] C.H. Ahn, J.H. Kwon, J.C. Joo, H.M. Song and G.G. Joh, "Water quality of a rural stream, the Hwapocheon stream and its analysis of influence factors", J. Kor. Soc. Environ. Eng., vol. 34, no. 6, **(2012)**, pp. 421-429.
[10] M.C. Gromarie-Mertz, S. Garnaud, A. Gonzales and G. Chebbo, "Characterization of urban runoff pollution in Paris", Wat. Sci. & Tech., vol. 39, **(1999)**, pp 1-8.

Authors

Sangleen Yun
Major: Environmental Engineering
Degree: Ph.D.
Affiliation: Korea Institute of Civil Engineering and Building Technology (KICT),
Positon: Senior Researcher

Seogku Kim
Major: Environmental Engineering
Degree: Ph.D.
Affiliation: Korea Institute of Civil Engineering and Building Technology (KICT),
Positon: Senior Research Fellow

Hyundong Lee
Major: Environmental Engineering
Degree: Ph.D.
Affiliation: Korea Institute of Civil Engineering and Building Technology (KICT), University of Science and Technology (UST)
Positon: Senior Research Fellow/Professor