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Contaminant loads of CSOs at the urban area in Korea

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ABSTRACT

Combined sewer overflows (CSOs) were examined in an urban catchment with three areas of 11.9, 19.9, and 57.7 ha located in northern Daegu city in Korea. A total of two non-rainfall run-off events were monitored and a variety of water quality parameters were analyzed. During the non-rainfall run-off, most water quality parameters, particularly organic pollutants, were fluctuated accordingly to the discharge of sewage flow. Event mean concentrations (EMCs) during the storm water run-off were shown higher than EMCs of non-rainfall events. The loading rates of overflows against total flow particularly, SS load was 14 times higher. Total CSOs emissions were expected to be around 1.38 to 5.18 kg/ha per event. Few obvious first flush phenomenons were observed due to the inflow of unknown sources and dilution with incessant duration of rainfall.

Keywords: Contaminant load; CSOs; EMCs; Urban area; NPS; Run-off

1. Introduction

According to the recent data of drainage systems in Korea, around 40.2% consists of the combined sewer system which is 47,510 km length of sewer pipelines. Since the system has been designed to transport and treat both foul sewage derived from municipal sources and stormwater contaminated by sediments from catchment surfaces, the high proportion of deposited sediments in the watershed is causing the system to be overloaded without proper treatment through combined sewer overflows (CSOs). As a consequence, the local receiving waterbodies are being significantly contaminated especially when the capacity of treatment works is exceeded during the period of high rainfall. The enhanced water quality management policies can be established on the basis of controlling storm water run-off, particularly controlling CSOs.

The incorporation of pollutant overflows into combined sewer systems from urban areas has persistently described through all over the world because of economic issues involved in providing enough capacity to the system to convey all peak storm discharges to the treatment plants as well as to prevent overflows [1]. Overflows from combined sewer systems are provided for converting the excess water to the nearest water bodies, causing a sudden pollution shock.

One of the leading current issues in the field of water environment management in Korea is to strength the nonpoint pollution source (NPS) management [2,3], where the percentage of nonpoint source

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pollution within the total amount of water pollution will be expected to be around 68–75% by 2020. Because CSOs problems occur usually in the urban area, the monitoring of CSO events during the period of non-rainfall, for comparison as well as the rainfall, is strongly required for the establishment of water quality policy. Subsequently, a lot of regulations on the management of CSOs have been implemented to improve water quality on the basis of areas where more intensive strategies have been required.

For a long time, various types of technologies for the management of storm water have been proposed to lessen the CSOs impact not only by reducing run-off volume but also by enhancing the storm water quality. Among the suggested practices, the most common approach is to install storage and/or retention basins to reduce the hydraulic volume peak [4]. Considering the need of treating CSOs effectively, the emerging practices based on physical/chemical processes are also being introduced in Korea.

Prior to the employment of new technologies for CSOs control, more careful and intensive measures for CSOs monitoring program should be proceeded through the storm water run-off characteristics from various types of land use, where CSOs are conveying a large broad spectrum of pollutants. Such accumulated CSOs data are required to introduce the management practices. Discharges from CSOs including urban surface run-off with domestic wastewater may cause damage to the receiving water sources severely, and thus the management of CSOs should be taken precedence in order for the establishment of water quality strategy.

In this context, the purpose of the study is thus to describe the experimental results of monitoring programs for non-rainfall and storm water run-off in several tens of hectare catchment area located in Daegu, Korea with a combined sewer system. This work investigates the contaminant properties of CSOs at the urban area, and to determine the extent of the first flush through pollutographs.

2. Materials and methods

2.1. Catchment description

Like most Korean cities, northern Daegu, the oldest and residential part of the city, has a combined sewer system. As shown in Fig. 1, three combined sewer systems which are adjacent to the sub-watershed of urban area were monitored eight times to collect run-off data during the storm events, and the same behaviors were made two times during the non-rainfall for the calculation of pollutant overloads. The catchment areas connected to the sampling site were 11.9, 19.9, and 57.7 ha, of which most parts are residential with impervious areas.

During the period of this work, each catchment had a tipping bucket flow gage at the outlet of the sewer system. Event mean concentrations were calculated from the grab samples and the measured flow rates.

2.2. Data collection

The samples during the rainfall were collected in the first time at 5 min intervals and the rest at proper intervals when the sampling cycle has started, and it has lasted until the end of overflow. In addition, 24 h sampling with 2 h intervals were performed during the non-rainfall.

The water quality data were collected two times for non-rainfall events and eight times for storm events. Table 1 describes the characteristics of total rainfall and average rainfall intensity for eight storm events. The storms had rainfall depths ranging from 4.5 to 32.5 mm and the duration ranged from 3 to 20 h. The antecedent dry days were ranged from 2 to 15 d.

All samples were prepared on the basis of reference, and materials were analyzed by standard methods [5]. The Event mean concentrations (EMCs) were calculated as a flow-weighted average of the concentrations of the individual grab samples. Monitoring data such as EMCs, run-off rate, and the parameters of water quality were analyzed to find the properties of NPS discharge. In addition, the concentration of pollutants during the initial period of storm water run-off was compared with the water quality data during the later stages of the storm event.

3. Results and discussion

3.1. General information on domestic sewer pipelines

According to the announced data by MOE, the total length of domestic sewer pipelines was 118,329 km in 2011. As shown in Fig. 2, the separate sewer system occupies less than the combined sewer system before the year of 2007. However, the domestic share of sewer pipelines was reversed because people are fully aware of the importance of water quality accompanied with the management of CSOs. Presently, 59.8% consists of the separate sewer system while 40.2% forms the combined sewer system pipelines.

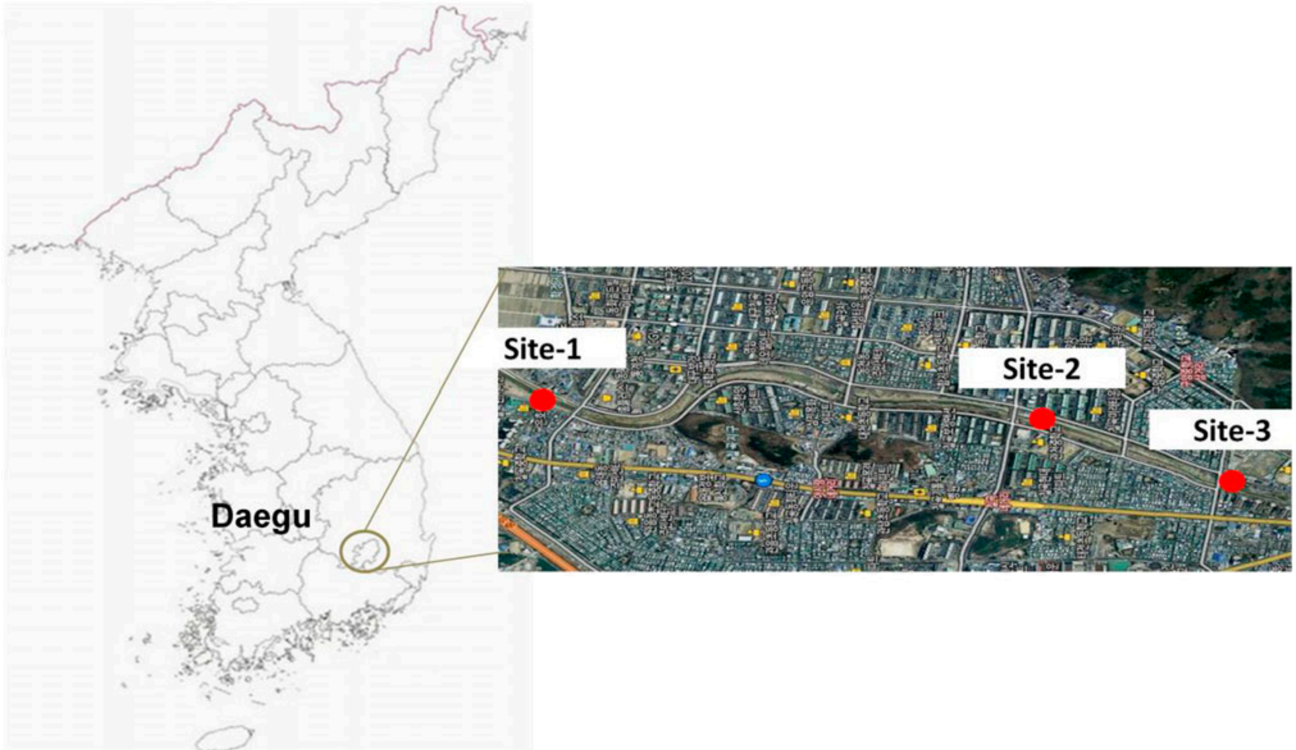

Fig. 1. Map of monitoring site.

Table 1
The characteristics of monitoring storms

Events		Event date	ADD (d)	Total rainfall (mm)	Rainfall duration (h)	Avg. rainfall intensity (mm/h)
Non-rainfall	E-1	29 September 2011	–	–	–	–
	E-2	26 September 2012	–	–	–	–
Stormwater	E-3	3 March 2012	7	25.0	18	1.4
	E-4	2 April 2012	3	20.4	9	2.3
	E-5	21 April 2012	15	29.5	20	1.5
	E-6	25 April 2012	2	23.8	8	2.9
	E-7	18 June 2012	3	15.0	15	1.0
	E-8	10 July 2012	3	32.5	14	2.3
	E-9	18 July 2012	2	14.6	10	1.6
	E-10	16 September 2012	3	4.5	3	1.5

3.2. Characteristics of non-rainfall events

Fig. 3 shows the profiles of pollutant concentration at the second site. Most organic water quality parameters such as BOD, COD, and TSS were fluctuated similarly to the discharge of sewage flow which typically showed the peak flow during the day and night time.

The average EMCs were BOD 89–117 mg/L, COD 127–166 mg/L, TSS 97–135 mg/L, T-N 10.9–12.6 mg/L, and T-P 1.3–1.4 mg/L, respectively. As summarized in Table 2, the concentration of water quality parameters was generally lower than expected to be flowed into the sewage treatment plant, which are thus causing the operational problems due to the low inflow

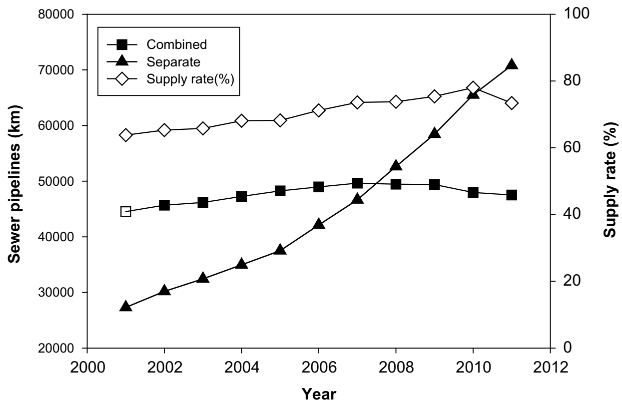

Fig. 2. Current status of domestic sewer pipelines.

concentration. Poor and inadequate pipeline facilities are also attributed to the difficulties on operating treatment works.

3.3. Characteristics of storm water events

Fig. 4 shows the profiles of pollutant concentration at the second site of event no. 3. Most water quality parameters were fluctuated with the variation of rainfall depth. The more rainfall dropped, the higher concentration was observed at the most site.

Table 3 shows the average EMCs during the storm water events where each water quality parameter was BOD 114–130 mg/L, COD 204–242 mg/L, TSS 117–202 mg/L, T-N 14.3–18.2 mg/L, and T-P 1.77–2.12 mg/L, respectively.

EMCs during the rainfall events were higher than EMCs of non-rainfall events, and the similar trend was shown in the pollutant loads. As shown in Table 4, the loading rates of overflows against total flow during the rainfall were ranged 28–39% depending on the analyzed parameters.

Table 2
Summary of EMC during non-rain fall event

		EMC (mg/L)				
		BOD	COD_{Cr}	SS	T-N	T-P
Avg.	Site-1	89	137	97	11.6	1.31
	Site-2	117	166	119	12.6	1.32
	Site-3	91	127	135	10.9	1.40

In addition, the considerable distinction was observed at the point of comparison with non-rainfall, where SS load was 14 times higher. SS has been revealed as the predominant pollution vector in the sewer system and thus a key parameter to be monitored for the management of CSOs [6].

Because most catchment areas are influenced by a combined sewer system, the sewer sediments might be expected to be retained during the dry seasons which would contribute to the first flush under storm weather conditions [7].

The accumulated amount of sediments in the sewer systems was calibrated to be 1.75–6.5 kg/ha, taking into account the SS loading during the non-rain fall events and storm water events. During the storm water events, the total CSOs emissions were expected to be around 1.38–5.18 kg/ha per event. Fig. 5 presents the total TSS sediments, which were less amount compared to be the reported value of average 14.51 kg/ha per event [8].

3.4. First flush

The normalized mass was plotted against the normalized run-off volume for each water quality items. Fig. 6 presents the first flush for organics and nutrients for event no. 10 at Site-2. SS, BOD, and COD

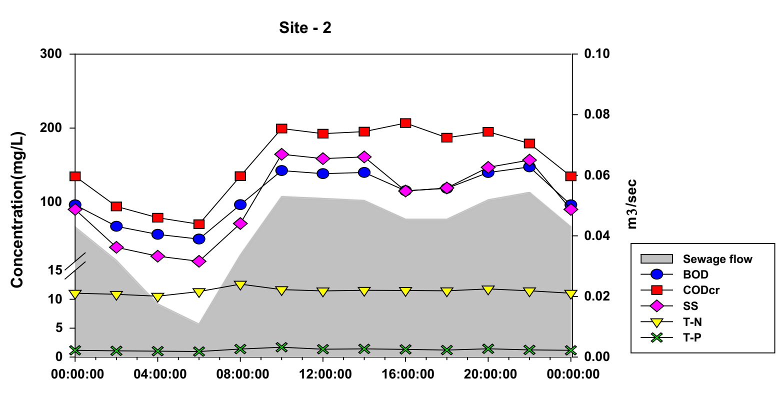

Fig. 3. Variations of pollutant concentration during non-rainfall event.

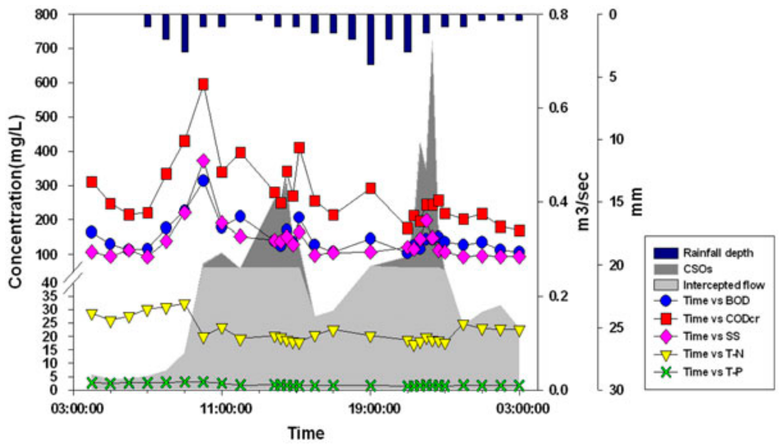

Fig. 4. Variations of pollutant concentration at Site-2 during rainfall event (E-3).

Table 3
Summary of EMC during storm water event

		EMC (mg/L)				
		BOD	COD_{Cr}	SS	T-N	T-P
Avg.	Site-1	114	204	171	14.3	1.77
	Site-2	130	242	202	18.3	2.03
	Site-3	130	229	181	14.8	2.12

as organics had a larger first flush than the other pollutants, which was supported by the reference [9] that observed the first flush in TSS and COD from highway surfaces. Generally, the existence of the first flush phenomenon is influenced by the type of run-off pollutants and not only by the size of surfaces but also by the catchment areas.

Few obvious first flush phenomenon could be observed any more for other events regardless of site characteristics, although there have been a lot of works to characterize the first flush associated with catchment characteristics and weather conditions.

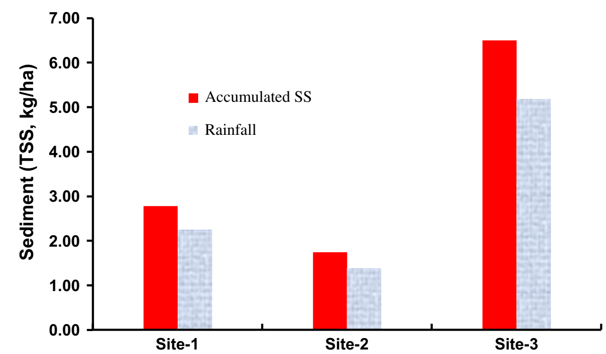

Fig. 5. Accumulated sediments in the sewer systems.

Different from the indicated concepts on the first flush, these are caused by the characteristics of monitoring sites for this work which were strongly governed by the infiltration/inflow such as defective pipe, pipe joints, cross-connections, and direct inflow of low concentration due to the dilution by constant duration of rainfall.

Table 4
Analysis on pollutants load

Loading rate (%)		BOD	COD_{Cr}	SS	T-N	T-P
Overflows/total flow	Site-1	33.1	33.0	33.6	31.8	32.3
	Site-2	38.2	38.4	37.9	37.3	38.6
	Site-3	27.6	31.7	27.8	27.6	29.3
	Avg.	33.0	34.4	33.1	32.2	33.4
Overflows/ non-rainfall	Site-1	382	436	612	369	409
	Site-2	982	1,319	2,407	1,196	1,248
	Site-3	1,106	1,507	1,057	1,200	1,034
	Avg.	823	1,087	1,359	922	897

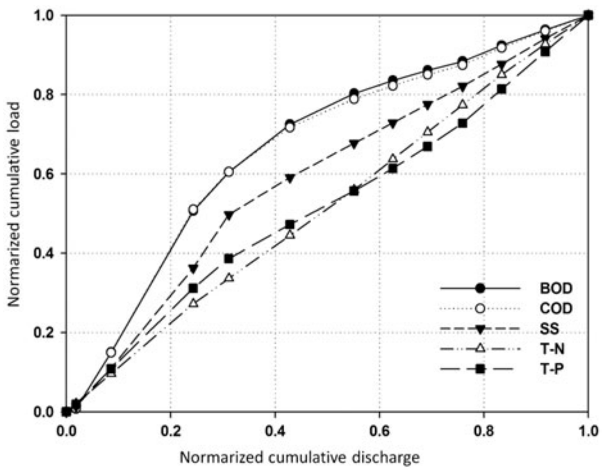

Fig. 6. Plots of cumulative load fractions and a function of cumulative run-off volume at Site-2.

4. Conclusions

Urban catchment with three areas of 11.9, 19.9, and 58.7 ha connected to the combined sewer systems were examined during the non-rainfall run-off events and the storm water run-off events.

(1) In Korea, 59.8% consists of the separate sewer system and 40.2% occupies the combined sewer system pipelines.
(2) BOD, COD, and TSS were fluctuated with the discharge of sewage flow during the non-rainfall run-off events.
(3) During the storm water events, the total CSOs emissions were calculated to be around 1.38–5.18 kg/ha per event.
(4) Few obvious first flush phenomenon could be observed any more for other events regardless of site characteristics.

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