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Assessment of Non-point Pollutants and Runoff Characteristics in Urban Area, Korea

Park, Jae Young, I-Song Choi and Jong-Min Oh*

(Center for Environmental Studies & Department of Environmental Science and Engineering,
Kyung Hee University, Korea 449-701)

The objectives of this study were to understand the runoff characteristics of the non-point sources originating from impervious surfaces and to assess their effect on the aquatic environment in the urban areas. The concentration of pollutants (SS, BOD, COD and T-P) except for T-N showed the highest value in runoff from road, and event mean concentration (EMC) also showed high value from road. The pollutants discharged from road showed a higher concentration in the beginning stage (0～30%) of progressive percentage of rainfall. The contribution percentages of non-point sources by load were 44.9% for SS, 11.2% for BOD, 21.4% for COD, 11.4% for T-N and 8.1% for T-P in the total load of pollutant discharged through sewer. From our results, the road was a significant potential source that deteriorated water quality of the streams and lakes in the vicinity of the urban area during the rain period. Therefore, counter plan is required to reduce pollutant concentration on the road from non-point sources in the urban area. Also, since pollutant concentration in the beginning stage of rainfall was quite high, road cleaning seems to be one of the very useful methods to prevent inflowing of pollutants to the aquatic environment.

Key words : point source, non-point source, road and roof, impervious surface, runoff, event mean concentration (EMC)

INTRODUCTION

Since the early 1960s, rapid industrialization and urbanization in Korea have led to the increase of population in urban areas, resulting in a variety of environmental pollution. In particular, runoff from the urban areas directly imposes pollution on the receiving waters. The occurrence of pollution generated from urban areas can be largely divided into two sources, point and non-point. Although the pollution originating from point sources is very large, it is controlled relatively well by advanced environmental facilities. Non-point sources, however, are very difficult to be controlled because occurrence routes of them are very diverse and extensive (Bedient *et al.*, 1978; Hunter *et al.*, 1979; Novotny, 1995). Tonderski *et al.* (1996) reported that the non-point sources had been the dominant case of water pollution in developing countries but they were not managed as properly as point sources with less public awareness of the environment. Therefore, importance of control for non-point sources has been increased and runoff characteristics of them must be correctly estimated to prevent the pollution of stream water quality.

Excessive development of satellite towns near a large city has been essentially accompanied with the massive pavement of natural soil surfaces and with the conversion of the natural sewer system into man-made channel networks.

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* Corresponding Author: Tel: ＋82-31-201-2461, E-mail: jmoh@khu.ac.kr

Therefore the pollutants accumulated on impervious surfaces of urban areas such as roads and roofs could not only be leached out but also cannot be reduced by adsorption reaction of the soil surface and, after all, they would be transported to the neighboring rivers and lakes through man-made channel networks.

At the end of 1970s, the U.S. set up a plan to decrease the load of pollutants from non-point sources, categorized them in details, and thereafter has strictly managed them (Schmidt, 1986). Since the environmental ministration of Japan founded the association of investigation upon the non-point source in 1978, they have closely examined the domestic non-point sources (Yamada, 1991). While many advanced countries have made efforts to define the non-point sources and to develop the optimum management technique of them (Lynch and Corbett, 1990), few studies have been attempted in Korea (Bang *et al.*, 1997), nevertheless the influence by non-point sources on the hydrosphere is growing in urban areas.

The objectives of this study are to understand the runoff characteristics of the non-point sources originating from impervious surfaces such as roads and roofs and to estimate contribution of them to aquatic environments (especially, urban stream).

MATERIALS AND METHODS

Site description

Shingal is a small town (26,445 residents on 2001) in Yongin located to the south of the capital city, Seoul, Korea. The local stream of Shingal (called Shingalcheon) flows from the east to the west across Shingal town, and ultimately to Shingal Lake. Shingal Lake is a very important (2.29 km^2) irrigation water source for local agriculture.

Figure 1 shows the detailed sampling sites. A road and roof were selected as sampling sites of non-point sources in this study. Sampling sites of precipitation and storm sewer were selected for using as a comparison data. Total area of the roads including parking lots was 131,561 m^2 (29%) in the study area, and the other area of 324,659 m^2 was investigated as the roofs. The sampling site of a road paved with asphalt was on the bridge Sangal that spans the Shingalcheon. This site was selected as one of the representative points to investigate the effect of human activities and vehicles and was 30 meter away from the heavy traffic zone of the town center. Precipitation and runoff from roof was collected on the Shingal city office located in the center of commercial and residential areas.

Since the sewer system of Shingal is consisted of the combined sewer system, all of the sewage and industrial wastewater comes up to Shingalcheon regardless of precipitation. Effluent of three different combined sewers in the middle of Shingalcheon, specified as SW1, SW2 and SW3 in Figure 1, was sampled. Their sites were greatly influenced by domestic waste and industrial waste originating from Shingal town. The storm sewer does not flow out to Shingalcheon on sunny days. During the heavy rain the flow rate tremendously increases. After all, precipitation

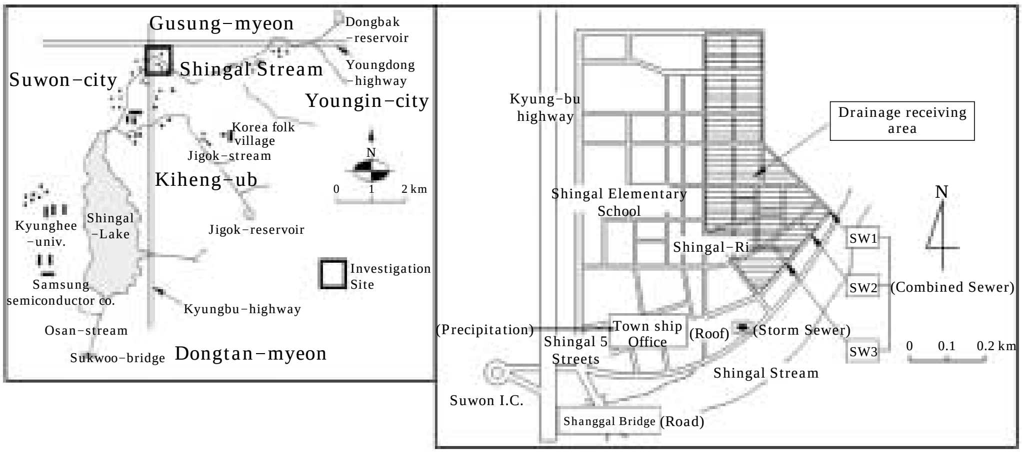

Fig. 1. Map of the experimental watersheds and location of sampling sites.

including large amounts of pollutants from non-point sources flow out through the storm sewer. Therefore, the storm sewer flow must be estimated and distinguished from the other flow to evaluate the combined sewer flow and to understand influence of non-point sources on receiving water. Combined sewers carry a mixture of sewage /wastewater (dry weather flow) and storm/rainfall runoff.

Sampling methodology

Precipitation during each test day was collected by using a clean 20 L polyethylene bottle with a 30 cm diameter funnel set up on the rooftop of the town office. In order to exclude the influence of other non-point sources, the runoff sample from the road was collected from a drain-outlet located under the Sangal bridge. Runoff from the roof was sampled from the downspout of Shingal town office. The roof was coated with paint, gently sloped and rugged.

Sampling of runoff from the road, the roof and the sewers was initiated as soon as the runoff from them appeared. During the precipitation, the runoff for the first few hours was sampled with a short interval, 20 minutes in this study, because a large amount of contaminants should be discharged into Shingalcheon at the beginning of the rainfall. The sampling interval was then extended to about 1～2 hours until the rain stopped. Sampling of sewage has been continued until the flow rate was recovered to water level of the dry weather.

Physicochemical analysis

The flow rate was determined *in-situ*. Samples brought to the laboratory were preserved at 4°C in a refrigerator until analyzed. The volumetric flow rate from the sewer was evaluated by measurement of flow velocity and the cross sectional area of the drainpipe, and the volumes of runoff from other sampling sites were directly determined by using a vessel. The collected samples were analyzed according to the Standard Methods (APHA *et al*., 1995). Analysis was performed by appropriate methods such as;

- Suspended solids (SS): Filtration, drying at 103～105°C and weighing (Section 2540 C).
- 5-day biochemical oxygen demand (BOD_5): Dilution water not seeded technique using membrane electrode method, DO meter (YSI 58, USA) (Section 4500-O G, 5210 B).
- Chemical oxygen demand (COD): Closed reflux, titrimetric method using dichromate for oxidation (Section 5220 C).
- Total nitrogen (T-N): Summation method (T-N = TKN + NO_3-N + NO_2-N).
- Total Kjeldahl nitrogen (TKN): Digestion, distillation using Kjeldahl flask (Section 4500-N_{org} C).
- Nitrate-nitrogen (NO_3-N): Ultraviolet spectrophotometeric method (Section 4500-NO_3 B).
- Nitrite-nitrogen (NO_2-N): Ion chromatographic method (Section 4500-NO_2 C).
- Total phosphorus (T-P): Persulfate digestion and ascorbic acid method (Section 4500-P B).

RESULTS AND DISCUSSION

Concentration of pollutants in runoff with land uses

The range and mean concentration of pollutants in the runoff from the road, roof, sewers and precipitation during the investigation period were summarized in Table 1. The values of combined sewers in Table 1 were obtained from the total data of SW 1, SW 2 and SW 3. In land uses, the road showed the wide range and high concentrations for all items except for T-N. Especially, SS and COD of road samples showed much higher concentration than those of other samples, as 1,076 mg · L^{-1} and 375 mg · L^{-1} in mean concentration, respectively. The range and mean concentration of BOD in road samples was 1.6～285 mg · L^{-1} and 37.5 mg · L^{-1}, respectively. In general, the roads are likely to be impacted by environments such as pavement wear, vehicles, atmosphere and various maintenance requirements. Sartor *et al.* (1974) and Novotny (1995) reported that deposit matters from atmosphere generated by vehicles and urban area action significantly influenced the roads.

The range and mean concentration of each pollutant from the roof were lower than those from other sites. The mean concentration of BOD and COD in roof samples were 4.9 mg · L^{-1} and 45 mg · L^{-1} and that of T-N and T-P were 2.43 mg · L^{-1} and 0.28 mg · L^{-1}, respectively. Judging from the data that mean concentrations of each pollutant in the roof sample showed similar values with them in precipitation (Table 1), the concentrations of each pollutant in the roof sample

Table 1. Concentration of pollutants for rainy days de-pending on land use in urban area.

Land use	SS	BOD	COD	T-N	T-P
	(mg · L^{-1})				
Road	15～5,960 (1,076)[a]	1.6～285 (37.5)	26～1,645 (375)	1.89～25.86 (6.61)	0.15～7.93 (1.79)
Roof	2～101 (20)	1.1～14.2 (4.9)	16～140 (45)	1.40～5.19 (2.43)	0.04～0.88 (0.28)
Combined sewer	6～629 (149)	2.4～159 (29.0)	16～346 (144)	1.59～26.47 (8.37)	0.15～3.16 (0.87)
Storm sewer	22～224 (100)	4.3～6.5 (5.2)	72～80 (77)	3.37～5.69 (4.20)	0.08～0.53 (0.27)
Precipitation	2.8～25 (15)	3.0～3.8 (3.5)	17～48 (31)	1.50～4.44 (2.22)	0.05～0.25 (0.16)

[a] Mean concentration

were mainly affected by precipitation. As sampling area of roof was located at a height of 3.5 meter from ground, comparatively heavy weight deposit matter was difficult to accumulate on that site and, even though deposited matter was accumulated on the roof, it is possible to be redispersed by wind. It was verified that mean concentration of SS in roof sample was 20 mg · L^{-1} and this value was little more than that of precipitation (15 mg · L^{-1}). Simply calculating, just 5 mg · L^{-1} was accumulated with deposited matter on roof, and therefore potentiality of pollution by runoff from roofs was not much in this study (Duncan, 1999; Chiew and McMahon, 1999).

The concentrations of all pollutants originated from the storm sewer were lower than those from the combined sewer. The region for the present study consists mostly of the combined sewer system, and the whole length of the storm sewer is relatively short, so that collecting of runoff through the storm sewer is very limited. In addition, all deposits on the roads could not be added to the runoff of the storm sewers because of removal of them by periodic cleaning and/or movement away by violent winds. In other words, it required tedious attempts to achieve an accurate sampling from storm sewers during the first flushing. The mean concentration of T-N was the highest in the combined sewer as 8.37 mg · L^{-1}. Accumulated deposits on the roofs and roads would be introduced to the combined sewer, accompanying with domestic sewage.

The SS concentration of precipitation was in the range of 2.8～25 mg · L^{-1}. The high concentration for SS in precipitation seems because frequent construction works in the vicinity of the study site led to a great increase of falling dust for survey period. A similar tendency was found in Japan, located closely from Korea with a similar climate. Wada (1985) reported that SS concentration of precipitation was in the range of 1～42 mg · L^{-1} in urban areas.

Assessment by event mean concentration (EMC) in runoff with land uses

Because the concentration of pollutants during the storm event changes with a wide range by amount of precipitation, evaluation by selected concentrations of pollutants has a significant defectiveness. A single index known as Event Mean Concentration (EMC) can be used to correctly evaluate characteristics of runoff from each non-point and point source considering amount of rainfall (USEPA, 1983; Novotny and Olem, 1994; Sansalone and Buchberger, 1997; Smullen *et al.*, 1999). The EMC indicates a flow-weighted average of constituent concentrations. The EMC for an individual storm event is defined as the total pollutant load divided by total runoff volume, as follow equation.

$$EMC = \sum Q_i C_i / \sum Q_i$$

Where, Q_i is the time variable flow, C_i is the time variable concentration and i is the rainfall duration (time). The EMC values for each storm event are summarized in Table 2.

Comparing at 66 mm of rainfall, EMC value of pollutants from the road investigated in this study was higher than that from roof and sewers. This tendency was similar to the result of "**Concentration of pollutants in runoff with land uses**". The highest rainfall intensity (9.5 mm · hr^{-1}), the value of rainfall amount divided by rainfall time, among the road samples, which was 21 mm of rainfall for 2.2 hr, resulted in much higher values of EMC than other rainfall intensity. Also, the EMC values at 21 mm of rainfall for 2.9 hr were relatively high. EMC value was not influenced by only rainfall amount. EMC values at 66 mm of rainfall that is the largest rainfall amount were not higher than those

Table 2. EMCs for individual storm event with land use in urban area.

Land use	Rainfall (mm)	Rainfall time (hr)	SS	BOD	COD	T−N	T−P
			(mg · L^{-1})				
Road	5	2.0	574	−	98	2.67	1.43
	66	10.8	242	9.0	113	2.42	1.04
	21	2.9	895	16.3	270	5.78	1.57
	21	2.2	1,688	15.8	366	5.42	1.64
Roof	5	2.0	10	−	27	2.26	0.50
	66	10.8	25	3.5	43	2.06	0.11
Sewer	8	2.5	169	14.3	169	8.64	0.43
	66	10.8	157	26.0	96	4.30	0.89
	Dry weather period		64	31.5	189	18.40	1.50

− : No data

at 21 mm of rainfall. This reason seemed why rainfall time for 66 mm of rainfall was about 5 times longer than that for 21 mm of rainfall. From this result, we know that a large quantity of precipitation for a short time causes high EMC values of runoff. Therefore, rainfall intensity is a more significant factor to EMC value. This tendency was the same for roof and road.

Evaluation by EMC showed the actual concentration of each pollutant in runoff with land use. EMC values from sewers increased compared with concentrations (see Table 1) because the effect of the flow rate was excluded. While BOD concentration of road (37.5 mg · L^{-1}) was higher than that of combined sewer (29 mg · L^{-1}) in mean (Table 1), combined sewer had higher EMC value for BOD (26.0 mg · L^{-1}) than road (9.0 mg · L^{-1}) at 66 mm of rainfall (Table 2). EMC value of T−N was the highest in runoff from sewers as 4.3 mg · L^{-1} at 66 mm of rainfall.

All pollutants except SS investigated from sewers showed higher EMC values for dry weather than for rainy weather (dilution effect). In general, runoff from combined sewer includes mainly domestic waste for dry weather. Therefore high EMC values of sewer seemed to be influenced by domestic waste for dry weather. Roof also showed the least value for EMC.

Variation of concentration in runoff from road with progression of rainfall

From the previous study, we could know that the road was the most important pollution source (Novotny, 1995). Also many other studies reported that road in urban areas had discharged the highest non−point pollutants among the land uses (Sartor *et al.*, 1974; Rimer *et al.*, 1978; Novotny, 1995). Thus, characteristics of runoff from road with progression of rainfall need to set up the effective strategy for control of non−point sources. Figure 2 shows the variation of concentration for SS, COD, T−N and T−P in runoff from roads with progression of rainfall. Rainfall intensities of each storm event were 2.5, 6.1, 7.2 and 9.5 mm · hr^{-1}.

In Figure 2, among the results of the average rainfall intensities, the intensity of 2.5 mm · hr^{-1} showed the least variation of concentration for all pollutants presented with progression of rainfall. Since deposited matters accumulated on roads are transported by rainfall, rainfall intensity greatly influences on the concentration of each pollutant. Therefore low concentration of each pollutant in runoff at low rainfall intensity (2.5 mm · hr^{-1}) was due to not transporting all of the accumulated matters on roads. On the other hand, the concentrations of all pollutants at high rainfall intensities of 7.2 and 6.1 mm · hr^{-1} were high. More detailed data for rainfall intensity is required to understand the range of rainfall intensity influencing on the concentration of pollutants in runoff from roads.

The first flush (less than 30% of progression of rainfall in this study) greatly contributed to the concentration of each pollutant in runoff from roads. The high concentration of pollutants in runoff by first flush would be often seen at the impervious surface such as an asphalt street (Rimer *et al.*, 1978; Delleur, 1982). The concentrations of all pollutants were extremely high at the beginning stage (in the range of 0∼30%) in progression of rainfall (Fig. 2). The concentra-

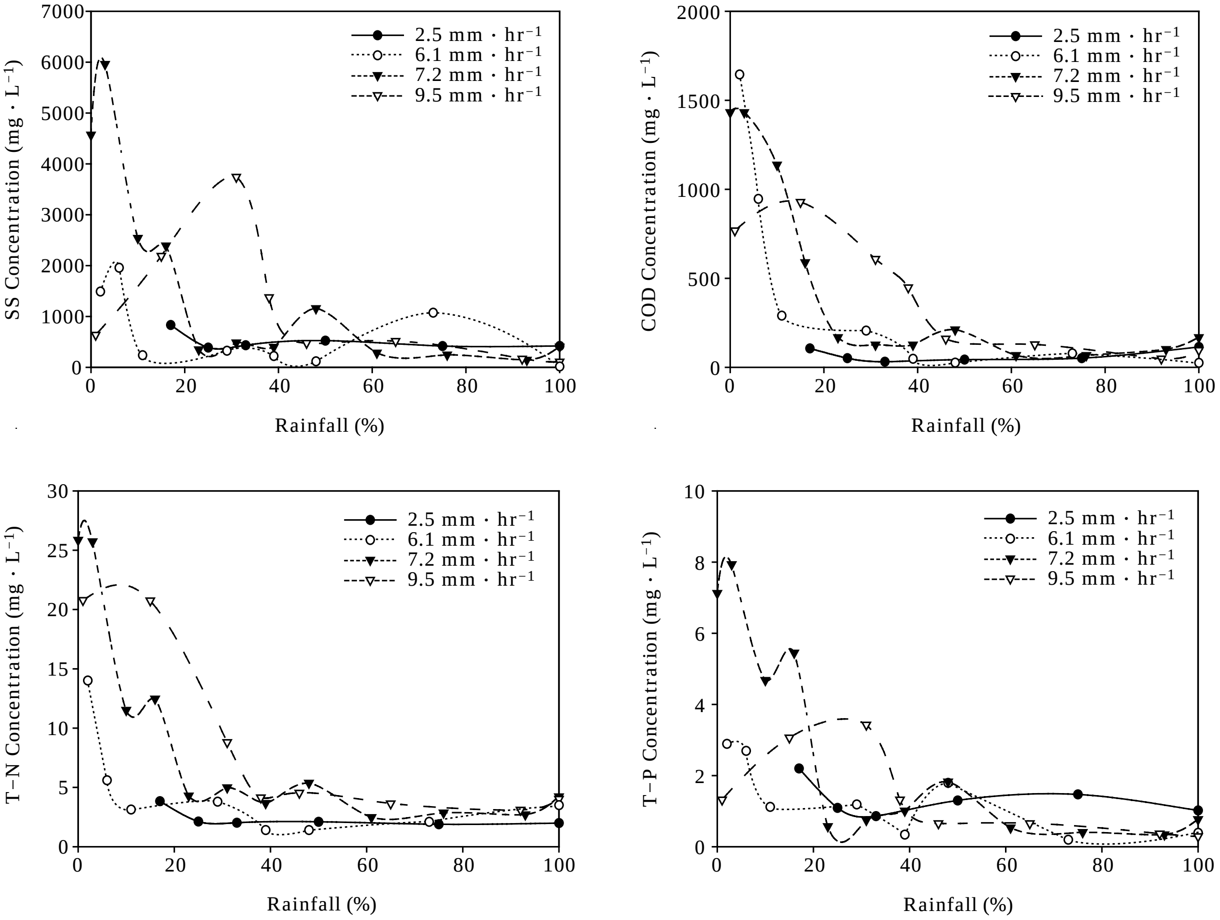

Fig. 2. Pollutographs for each average rainfall intensity on the road as a function of rainfall.

tions of SS, T−N and T−P at 7.2 mm · hr^{-1} of rainfall intensity especially showed the highest value at 3% of progression of rainfall, as about 5,960 mg · hr^{-1}, 25.8 mg · hr^{-1} and 7.9 mg · hr^{-1}, respectively. The concentration of COD at 6.1 mm · hr^{-1} of rainfall intensity was the highest value at 2% of progression of rainfall, as about 1,645 mm · hr^{-1}. Therefore, the beginning stage (0～30%) of progression of rainfall must be focused to reduce pollutants in runoff from roads.

Estimation of load by rainfall intensity with land uses

It is not simple to quantitatively estimate load of pollutants discharged from non−point sources during rainy days because of significant factors such as the amount of rainfall, the antecedent of dry periods and the effect of on−going construction works. In this study, we tried to estimate total load by rainfall intensity with land use. Table 3 shows the load of pollutants with land uses during each rainy day. The mean load of SS for rainfall intensities from the road was 3,713 mg · m^{-2} · hr^{-1}, and for BOD, COD, T−N and T−P were 68, 981, 20 and 6.9 mg · m^{-2} · hr^{-1}, respectively. The road had much higher values of load for pollutants than roof. The SS load especially discharged from the road surface during the rainy day was 28 times greater than that from the roof.

The COD load of precipitation for 6.1 mm · hr^{-1} of rainfall intensity was higher than that of roof. This result was quite far from the preliminary expectation that the pollutant load of precipitation would be lower than that of roof. The sampling site of the roof was a plane with a wide area and the surface of it was very rough. Therefore, it seems that some of the organic matters in runoff were occluded or adsorbed onto the rough surface of the roof during their moving to outlet. Oh *et al.* (1996) reported that waste concrete was a good treatment media for removal of SS, BOD, COD and T−P. More detail data is required to understand moving dynamics of organic matters on roof surface.

In the sewer, the load of pollutants was larger for 6.1 mm · hr^{-1} of rainfall intensity than for 3.2 mm · hr^{-1}. In particular, the loads of BOD (259 mg · m^{-2} · hr^{-1}) and T−P (8.8 mg · m^{-2} · hr^{-1}) at 6.1 mm · hr^{-1} of the rainfall intensity were about 4 times of those for 3.2 mm · hr^{-1}. However, the load of COD (756 mg · m^{-2} · h^{r-1}) at 3.2 mm · hr^{-1} was greater than that for 6.1 mm · hr^{-1}. This trend was shown in the result of EMC value (Table 2). This reason seemed to be the irregular wastewater originating from neighboring industries including a large amount of hardly dissolved organic matters. Summing up the results, it was obvious that the high rainfall intensity caused much load of pollutants in runoff from all the sampling sites. However, any particular relationship between rainfall intensity and load of pollutants was not found in this study.

Estimation of annual load from non−point sources

Annual contribution of non−point sources to the total pollution was estimated, and summarized in Table 4. While the point sources consistently discharge various pollutants, non−point sources intermittently do. In accordance, annual evaluation should be more desirable to verify the contribution percentages of the non−point source. Precipitation in Korea is usually intensive in the summer season, June to September, but rare precipitation occurs throughout the rest of the year.

The point source load was calculated by the data of the Table 2 which presented the sewer discharge amounts for one day obtained by continuous monitoring during the dry weather with the assumption that one day sewer discharge amounts was immutable for all year round. Following the calculation, the annual load of point sources for SS, BOD, COD, T−N and T−P were 180.4 ton · yr^{-1}, 93.38 ton · yr^{-1}, 531.6 ton · yr^{-1}, 57.0 ton · yr^{-1} and 4.34 ton · yr^{-1}, respectively.

In order to analyze the load of non−point sources, two methods were attempted, one on the basis of discharge load and the other of outflow load in this study. In the former approach, the load was evaluated for the roads and roofs, whereas the latter considered only the outflow of sewers.

In the former case, we divided pollutants loads of road and roof in Table 3 with the precipitation of that rainfall event and obtained unit loads (weight per mm) of road and roof. Then unit loads were converted into annual non−point source loads by multiplied annual precipitation (1,373 mm · yr^{-1}). Total loads of annual pollutants were determined by added the annual non−point source loads of roads and roofs during the rainy days and the point source loads of sewer during the dry days.

The latter approach was concerned only with the outflow of the sewers. The loads of non−point sources were obtained by subtracting discharge amounts from sewer during the dry days from those during the wet weather, and unit loads (weight per mm) of non−point sources were determined by dividing the loads of non−point sources with the rainfall. The annual loads of non−point sources were determined by multiplying the annual rainfall (1,373 mm · yr^{-1}) by unit loads of each non−point source. Total annual pollutants loads at the sewers were determined by adding the annual non−point source load at the sewers and the annual point source at the sewers during the dry weather.

In Table 4, the annual loads of SS, BOD, COD, T−N and T−P in runoff from road and roof were

Table 3. Individual load of pollutants with land use for the rainy days in urban area.

Land use	Rainfall Intensity (mm · hr^{-1})	SS	BOD	COD	T−N	T−P
		(mg · m^{-2} · hr^{-1})				
Road	2.5	2,486	−	425	12	6.2
	6.1	1,609	60	749	16	6.9
	7.2	5,016	89	1,505	33	8.9
	9.5	5,741	54	1,245	18	5.6
Roof	2.5	22	−	62	5	1.2
	6.1	58	8	101	5	0.3
Sewer	3.2	757	64	756	39	2.0
	6.1	1,559	259	385	43	8.8
Precipitation	2.5	−	−	12	5	0.6
	3.2	56	−	153	5	0.5
	6.1	17	19	136	9	0.6
	7.2	−	23	103	4	0.3
	9.5	139	19	265	25	1.3

− : No data

Table 4. The individual unit load and pollutants load with land use in urban area.

Land use	Unit	SS	BOD	COD	T-N	T-P
Road	$kg \cdot mm^{-1}$	83.9	0.91	20.75	0.46	0.18
Roof		1.04	0.06	2.45	0.17	0.03
Sewer (non-point source)		106.9	8.55	105.2	5.32	0.28
Road+Roof	$ton \cdot yr^{-1}$	116.7	1.33	31.85	0.86	0.29
Sewer (non-point source)		146.8	11.74	144.6	7.30	0.38
Sewer (point source)[a]		180.4	93.38	531.6	57.0	4.34

[a] Dry weather period

116.7 $ton \cdot yr^{-1}$, 1.33 $ton \cdot yr^{-1}$, 31.85 $ton \cdot yr^{-1}$, 0.86 $ton \cdot yr^{-1}$ and 0.29 $ton \cdot yr^{-1}$, respectively. The percentages of loads from non-point sources to total loads of pollutants occupy 39.3%, 1.4%, 5.7%, 1.4% and 6.3%, respectively. However, calculating the non-point pollutants load from the sewer as the equivalent amount of total local precipitation (1,373 $mm \cdot yr^{-1}$), the values of SS, BOD, COD, T-N and T-P become 146.8 $ton \cdot yr^{-1}$, 11.74 $ton \cdot yr^{-1}$, 144.6 $ton \cdot yr^{-1}$, 7.30 $ton \cdot yr^{-1}$ and 0.38 $ton \cdot yr^{-1}$, respectively. The percentage of non-point source load to total pollutants load at sewer occupies 44.9%, 11.2%, 21.4%, 11.4%, and 8.1%.

This assessment for load of pollutants through the monitoring of runoff from roof and road and of combined sewer when the rainy and the sunny day is very rare until now, although it shows the characteristics of regional data. The difference between the two different approaches seems to be due that the build-up of fine sediment particles in the drainpipes was re-suspended by rainfall and discharged with the runoff. Therefore, the contribution of the non-point source loads from the sewers was higher than the sum of the road and roof.

CONCLUSIONS

Having rarely studied for non-point sources including sewers and roofs and impervious surfaces of roads in urban areas, accumulated data for them is insufficient and it is very difficult to appropriately manage pollution matter discharged from them. Therefore the concentration and load in runoff from different non-point sources during the storm events were carefully investigated in order to control non-point sources in the urban area.

The accumulated matters on the roads significantly influenced on the water quality of urban stream with their high concentrations and loads of pollutants. SS concentration from road especially was 1,076 $mg \cdot L^{-1}$ in average and this value reached 7 times the amount of that from the sewers. Also, runoff of pollutant matter from the road was concentrated in the beginning stage (0~30%) of progression of rainfall. Nevertheless the area of the roads occupied in the urban area (131,561 m^2) was much smaller than that of roofs (324,659 m^2), the total load of pollutant matter from the roads was extremely higher than that from the roofs. Thus, first flushed pollutants from the roads among the non-point sources need to be systematically managed with an advanced technique and methodology. According to our result (unpublished data), the removal amount of organic and inorganic matters by just cleaning on the road was up to about 54%. In addition, backward sewage disposal facilities must be urgently rearranged and up-graded in order to prevent the further contamination of streams and lakes. As a further study, a simulation model to estimate runoff of non-point sources must be developed with reliable factors such as population, land use, sewer system, and the season.

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