# CHARACTERIZATION OF NONPOINT SOURCES FROM URBAN RUNOFF

**Jae Young Park, Young Min Jo, and Jong Min Oh**
Institute for Environmental Science, Department of Environmental Science and Engineering,
Kyung Hee University, Kyunggi-Do, Korea

---

**Abstract:** This work was completed in partial fulfillment of an on-going research to discover the effective management of urban nonpoint sources. The current data was obtained from the area of Shingal, Kyunggi-do. The investigation was made focusing on the analysis of organic elements in runoff from impervious surfaces such as road and roof which are predominant sources of storm-runoff load and drainage. As a result of the investigation, the road was found to be most seriously contaminated and a significant potential source deteriorating the quality of streams and lakes in the vicinity of the town. Thus, it could be concluded that an effective and. systematic cleaning technique must be developed as soon as possible and be frequently applied to the road

---

**Key Words:** nonpoint source. urban runoff, water pollution, organic pollutant

## 1. INTRODUCTION

Since the early 1960s, rapid industrialization and urbanization in Korea have led to the increase of population in urban areas and contributed to a variety of pollution. In particular, urban runoff entails direct pollution of receiving waters, eventually the surface waters of streams and lakes. The urban runoff quality is closely related to nonpoint source (i.e. "the source of pollutants is randomly scattered and the resulting discharges enter aquatic system in diffuse routes manner such as rainfall, snow and wind"). Wastes are generated over an extensive area of land and the diffuse sources are not only difficult to be monitored but also to be controlled, while point sources can be well controlled based on the increase of the basic environmental facilities. Thus, although nonpoint source is the dominant cases of water pollution particularly in developing countries, they are not managed as properly as point sources.

The excessive development of satellite towns near a large city has been essentially accompanied by the massive pavement of porous surfaces and by the conversion of the natural drainage system into man-made channel networks. The accumulated contaminant materials on such impervious urban surfaces can be removed by rainwater runoff, and hence ultimately contribute to complex water pollution. While many countries have made effort to define the nonpoint source and to discover the optimum management technique (Lynch et al., 1990) (Schmidt et al., 1986), few studies have been fulfilled in Korea (Bang et al., 1997), though the influence by nonpoint source on the hydrosphere is of growing importance. At the end of 1970s, US set a plan to decrease the load of pollutants from nonpoint sources categorizing them in details, and thereafter has strictly managed (Novotny, 1995). Environmental Administration of Japan founded the association of investigation upon the nonpoint sources in 1978, and they have closely examined nonpoint sources (National Inst. of Env. Res., 1993). On the other hand urban nonpoint sources have not only been overlooked in Korea, but also practical endeavors have seldom been made in the management of nonpoint sources.

The objective of this study therefore is to emphasize the significance of nonpoint source and to investigate the typical domestic nonpoint sources by characterization of outflow pollutants from urban impervious surfaces such as road and roof, and drainage during common rains. The accumulated solids on the road surface and roofs during dry weather were also taken and analyzed for the comparison of weather condition. It will be the basic data useful for finding the optimum management technique of domestic nonpoint sources including potential means of control.

## 2. SITE AND ANALYSIS

### 2.1 Site Description

The Shingal Lake is 23 km$^2$ important irrigation water source for local agriculture. Shingal is a small town which is a typical satellite city located at the south of Seoul and rapidly expanding in population. The local stream, Shingalcheon, flows the east to the west across Shingal, ultimately running into the Shingal Lake. Fig. 1 illustrates the precise sampling sites. The present study was carried out with the runoff samples from impervious areas including paved roads and roofs. The sewer system of Shingal consists of the combined sewer system, it leads the sewage and industrial wastewater to

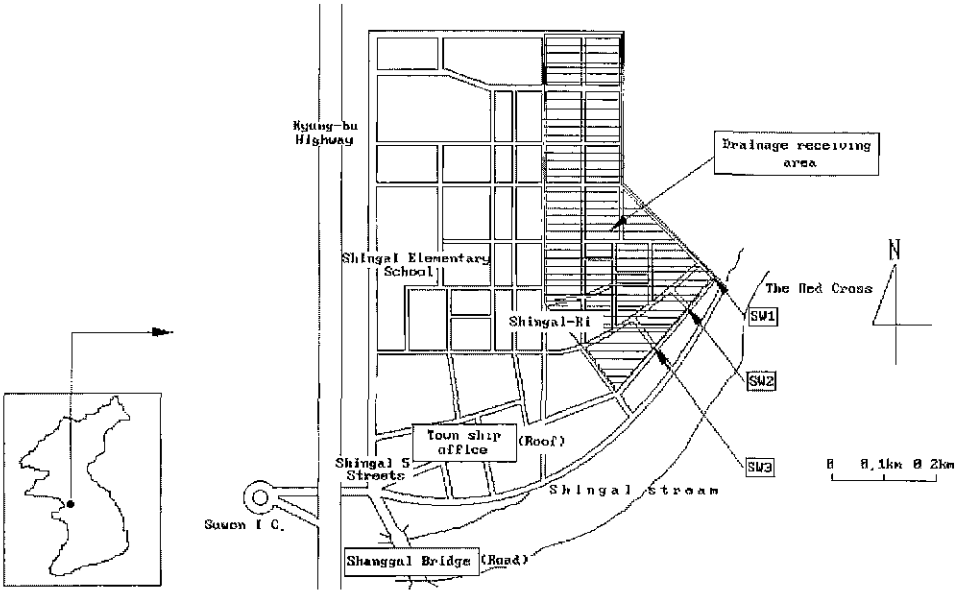


Fig. 1. Study Site

Shingalcheon either when it is rainy or not. Rainwater absorbs the highly concentrated contaminants of road and roof surfaces, then flows into Shingalcheon, and finally is introduced to the Shingal Lake. Thus three points from different drainage at the mid of Shingalcheon: specified as SW1, SW2 and SW3 were also selected for effluent sampling when it rains.

## 2.2 Sampling Method

Sampling of runoff was done from 12th of May, 1997 to 5th of June, 1998. Clean 20L-polyethylene bottles with a 30cm diameter funnel were placed on the rooftop of the town office for sampling of rainfall. Time delay from initiation of effluent on the road to arrival at the storm water drain-outlet differs depending on the rainfall intensity. Sampling was initiated as soon as effluent occurs. Runoff samples were collected while it was raining in a short interval with 20 minutes, because a large amount of contaminants is generally discharged at the beginning of rainfall. Sampling interval was then extended to about 1～2 hours until rain stops. Since it is impossible to make sampling directly from the road while it is raining, the outflow water was taken at a drainage under the bridge Sangal that passes over the Shingalcheon in order to investigate the effect of human activities and vehicles. It is 30 meters distant from the heavy traffic zone of the town center. The runoff from the roof was sampled in the water-shoot of Keeheung town office. The roof was painted, and rugged with mild slope. Volumetric flow rate of rainfall was evaluated by measurement of flow velocity and area. Sampling interval was the same with that of the road, and even after the rain stopped sampling was continued until the flow rate recovered to the common magnitude.

Sampling of dry deposition was done by means of a hi-power vacuum pump, which can reduce the presumable sampling errors. Since road surface contaminants are not distributed uniformly across the traffic lanes and solid particles would be driven to the roadside, we took the dry deposits from the roadsides.

## 2.3 Analysis of Pollutants

Samples brought to the laboratory by using 2L-polyethylene bottles and have been preserved in a refrigerator at 4°C till the analysis. The collected materials were analyzed according to the Standard Test Method for water quality. Table 1 shows the condition of analysis and method for SS, BOD, COD, $NO_3$-N, $NO_2$-N, TKN and TP. The flow rate, pH, EC, and DO were determined in-situ. The most prevalent heavy metal compounds in urban areas; Zn, Cr, Cd, Pb, as for reference were analyzed by using an atomic absorption spectrophotometer (AAS). Prior to the analysis of inorganic elements, the samples were pretreated by nitric acid, in order to assure the removal of organic matters including impurities.

Solids collected during dry periods were classified into the range A: 2 mm ~ 0.85 mm, B: 0.85 ~ 0.212, C: 0.212 ~ 0.106 and D: below 0.106 mm by means standard stainless sieves. Samples then were completely dried in an oven at 110°C. Dried samples were weighed after cooling, and pretreated by chloric acid (0.1N, 50mL) (Hopke, 1985).

**Table 1. Analysis Instrument for Organic Matters**

| Organic matter | Analysis instument and method |
|---|---|
| pH | pH meter (TOA HM-10P, Japan) |
| EC | EC meter (HANNA HI933100, Portugal) |
| SS | Vacuum Filtration (Glass Fiber Filters, GF/C) |
| BOD | DO meter (YSI 58, USA) |
| COD | Closed reflux, Titrimetric Method |
| T-N | Ultraviolet Spectrophotometric Screening Method |
| $NH_4$-N | Ultraviolet Spectrophotometric Screening Method |
| $NO_2$-N | Ultraviolet Spectrophotometric Screening Method |
| $NO_3$-N | Ultraviolet Spectrophotometric Screening Method |
| TKN | Macro-Kjeldal Method |
| T-P | Ascorbic Acid Method |

## 3. RESULTS AND DISCUSSION

### 3.1 Runoff Characteristics with Land Use

Mean annual rainfall of the study area is approximately 1,450 mm. However there has been big differences in rainfall yearly throughout the observations of past 13 years: minimum 809 mm to maximum 2,043 mm. In this section, runoff characteristics for rainy days were examined with respect to land use.

### 3.1.1 Characteristics of Runoff on the Road

The variation in concentration of organic matters in the runoff on the road is shown in Fig. 2. The road in this study is defined as the asphalt paved traffic lanes. The flow rate onto the road surface was average 0.146 L/sec, maximum flow was found in 5.2 hours since the initial rainfall. The average suspended solids (SS) concentration observed during rainy days was 680 mg/L. The highest concentration of SS appeared in 0.7 hours, which indicates the first flushing occurs at the beginning of rains. The first flushing is usually seen at the impervious surfaces as like asphalt street (Delleur, 1982).

COD was also highest (1,645 mg/L) at the beginning of rainfall, thereafter being decreased for first 1.2 hours of rain and maintained all but constant. It then increased in 7.8 hours as the rainfall decreased, being

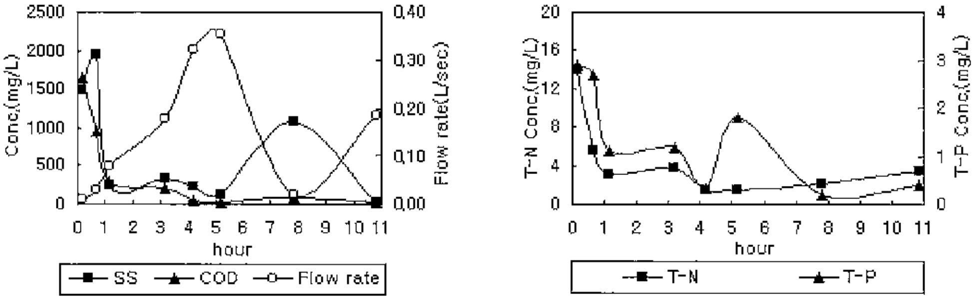


Fig. 2. Concentration of Organic Elements on the Road during Rainy Days

a similar to SS variation. Total nitrogen (T-N) and phosphate (T-P) which would influence the eutrophication of lake water were measured in their variation according to time. The average concentrations of T-N and T-P were 4.37 mg/L and 1.33 mg/L respectively. Both also were high at initial rainfall, and then began to vary with the flow rate.

### 3.1.2 Characteristics of Runoff on the Roof

The concentration of organic matters in the runoff from the roof is shown in Fig. 3. The average concentrations of SS and COD were 31 mg/L and 60 mg/L, which respectively correspond to 1/22 and 1/6.8 of those of the road. It means that human activity and vehicles produce a significant amount of organic matters. Thus, the roof that does not contact directly with anthropogenic sources might be less contaminated. Despite low concentrations of T-N and T-P (2.5 mg/L and 0.15 mg/L) on the roof, the occurrence of high peak at the first hour of rainfall implies the revelation of first flushing.

### 3.1.3 Characteristics of Runoff in the Drainage

The study region is served by a combined sewer system, so that when it is rainy the pollutants both from point sources such as domestic sewage and from nonpoint sources of rainfall would flow into the sewer and run out to the Shingalcheon. Three points (SW1, SW2, SW3) of drainage were selected for the investigation of runoff during rainfall. The total flow rate is the sum of three points, and the concentration of pollutants are evaluated as follows;

$$C = \frac{Q_{sw1}C_{sw1} + Q_{sw2}C_{sw2} + Q_{sw3}C_{sw3}}{Q_{sw1} + Q_{sw2} + Q_{sw3}} \qquad (1)$$

where $C$ is the average concentration of pollutants, $Q$ is the flow rate and $C_{sw}$ is the concentration of pollutant at each point.

The variation of organic materials versus time is shown in Fig. 4. The average concentrations of SS and COD are 182 mg/L and 155 mg/L, which are greater than that of the roof, but less than the road. It may be due to dilution of dense pollutants from the road surface by low concentration effluents discharged from domestic sewage, roofs and trees. In addition, such concentrations are closely associated with the degree of deposition in a sewer pipe. As flow increases through a pipe, the change of the depth, velocity and hydraulic radius results in less deposition, causing more effluents of solids (Pisano et al., 1981).

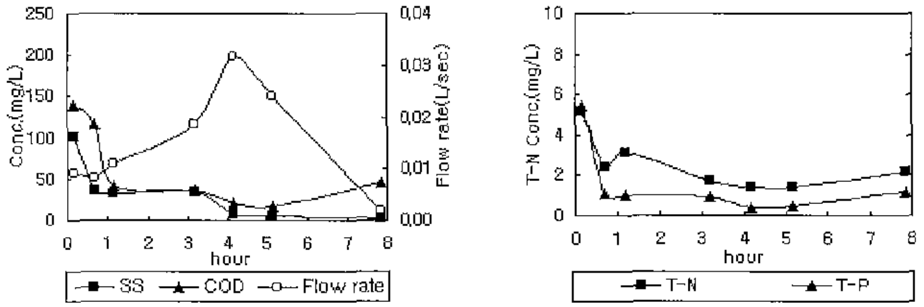


**Fig. 3. Concentration of Organic Elements on the Roof during Rainy Days**

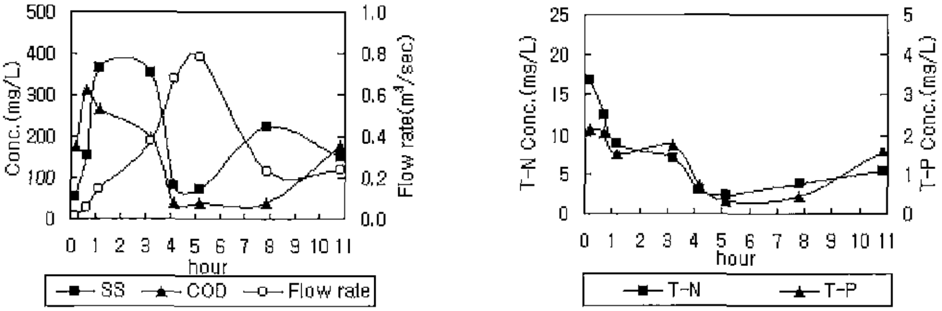


**Fig. 4. Concentration of Organic Elements on the Drainage during Rainy Days**

However, the flow velocity during this study when it was rainy was extremely high enough to ensure the data reliability. From the observation of T-N and T-P, it was found that the domestic sewage of point source contributes greatly to the contamination of sewer. During dry weather, daily average concentrations of T-N and T-P were 18.02 mg/L and 1.37 mg/L respectively, whereas they were 7.46 mg/L and 1.31 mg/L respectively when it was rainy.

Maximum and minimum concentrations of organic matters during the period of investigation are summarized in Table 2. The road was found to be more contaminated than other places. Thus, road cleaning practices must not be only for aesthetic, but also be highly effective to sweep the dust and dirt out. Removed contaminants from the road surface must also be well treated in order to prevent from flowing into drainage. The concentration of T-N is highest in the combined sewer, even much higher than that from the storm sewer.

## 3.2 Characteristics of Pollutants during Dry Period

### 3.2.1 Daily Variation of Pollutants at Drainage

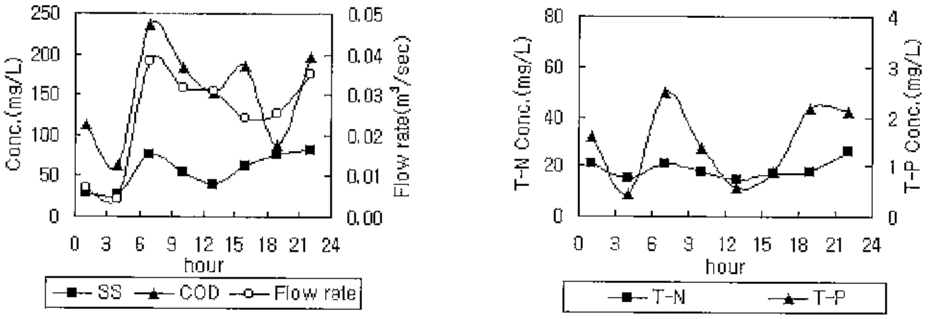
In order to compare the characteristics of runoff during rainfall, daily variation of pollutants discharged from the domestic sewer was investigated when it was not rainy Sampling at the same points was made every 3 hours from 10 o'clock in the morning to 10 o'clock next morning.

Fig. 5(a) indicates that the flow rate was great at 7 AM to 10 AM and at 10 PM. It is a typical behavior shown in urban sewage.

**Table 2. Concentration of Organic Matters for Rainy Days Depending on Land Use**

(Unit : mg/L)

| Organics<br>Land use | SS | BOD | COD | T-N | T-P |
|---|---|---|---|---|---|
| Road | 15~5,960 | 1.6~285 | 26~1,645 | 1.89~25.86 | 0.15~13.0 |
| Roof | 2~101 | 1.1~14.2 | 16~140 | 1.55~4.97 | 0.04~0.55 |
| Combined sewer | 28~629 | 2.4~159 | 17~240 | 4.28~26.47 | 0.15~3.16 |
| Storm sewer | 22~224 | 4.3~6.5 | 72~80 | 3.37~5.69 | 0.08~0.53 |
| Rainfall | 2.8~25 | 1~3.76 | 17~48 | 1.5~4.44 | 0.05~0.25 |



(a) (b)

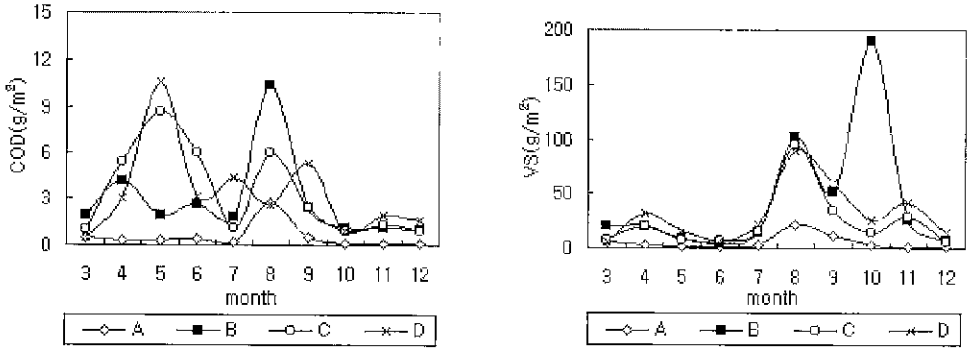
**Fig. 5. Concentration of Organic Elements at the Drainage during Rainy Days**

The periods show about two hours delay from rush hours for cooking, cleaning and bathing. The concentration of SS was highest with 82 mg/L at 10 PM, and lowest, 28~30 mg/L, at 1~4 AM. Due to bath and preparation for supper, the concentration of organic matters increased, and then decreased to minimum at midnight when the water seldom consumed.

COD was found maximum 236~292 mg/L at 7 to 10 AM. It differs from BOD which is highest at 10 PM, because rarely decomposable organic materials are more in the wastes discharged in the morning than in the evening. The highly contaminated effluents run directly into Shingalcheon without a swage waste treatment plant. The peak concentration of COD as well as other pollutants is much higher than the standard legislation (less than 40 mg/L) of effluent water quality from waste water treatment plant. In accordance, it can be concluded that it remarkably would deteriorate the water quality of streams.

3.2.2 Solid Deposits on the Road and Roof

The concentration and quantity of accumulated solids depend greatly on the length of time that had elapsed since the last rain, preceding rainfalls, population and vehicles. The monthly mass variation of deposits on the busy road is plotted in Fig. 6. Fig. 6(a) and (b) show the monthly variations of COD and volatile solids(VS) in



(a) (b)

**Fig. 6. Monthly Variations of COD and VS Loading on the Road during Dry Days**

the accumulated solids. The most COD was found in August (21.68 g/m$^2$), in which the absolute accumulation on the road surface was the highest. The high concentration in May might be due to the another dust, in particular very high in the fine particles. Smaller particles are apt to adsorb more organic materials. The volatile solids on the road were mostly organics, and were highest in August and lowest in June. It however still is 50 times as high as the roof. The results as a function of particle size are consistent with that of COD. The sampling point is one of the most contaminated places amongst urban land use, because is was the junction for five directions resulting in heavy traffic tie-up and crowed passage.

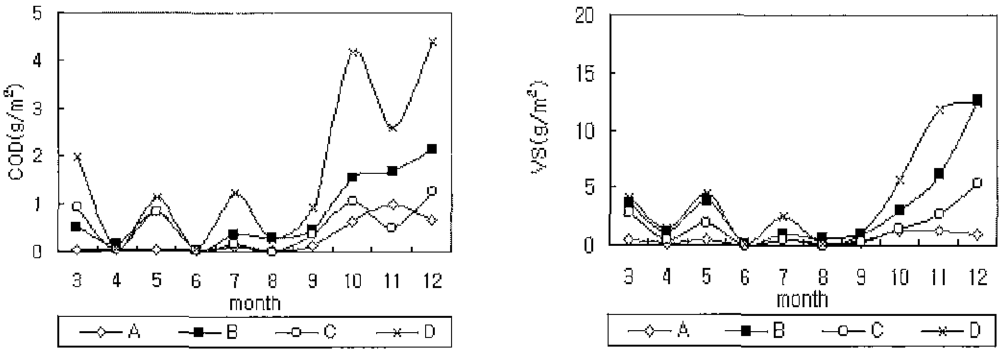
Figs. 7(a) and (b) show the monthly variation of accumulated solids on the roof. The COD was the lowest in June, indicating 0.18g/m$^2$. It is easy to predict the result since the roof usually is not disturbed by people and vehicles, but greatly influenced by industrial fly ashes and dustfalls. In addition, frequent rains in June enabled to wash the accumulated pollutants out. The VS was found in the order of particle size, D(4.37 g/m$^2$), B(3.31 g/m$^2$), C(1.55 g/m$^2$) and A(0.54 g/m$^2$).

### 3.3 Comparison of Solids Load between Dry and Wet Weather

The ratio of the load of organic pollutants between for dry and rainy days is summarized in Table 3. The average load was evaluated from multiplying individual load by rainfall hours. The accumulated particles on the road and the roof were sampled and the respective pollutant load was also evaluated. As a result, it could provide the preliminary information for the load when it rains since sampling for rainy days is not easy. The value of VS/SS in Table 3 indicates the VS load for the road

**Table 3. Ratio of Individual Load for Dry to Rainy Days**

| Land use / Element | Road | Roof |
|---|---|---|
| VS/SS | 8.49 | 39.4 |
| COD | 2.53 | 7.16 |
| Cd | 36.75 | 1150 |
| Cr | 7.9 | 95.0 |
| Zn | 54.8 | 190.91 |
| Pb | 190.0 | 162.5 |
| Al | 2.70 | 5.97 |



(a) (b)

**Fig. 7. Monthly Variations of COD and VS Loading on the Roof during Dry Days**

deposits to SS load for rainy days. It helps to minimize the error for the evaluation of SS for dry days. As can be seen in Table 3, the values are all greater than unity, which means that the accumulated solids on the road and roof are not only completely swept out while it is raining, but also some discharged effluents would be deposited in the drainpipes and water-shoots without washing-up. Thus, the effluents for rainy days are relatively low. A noticeable result is observed in Cd on the roof which is the highest ratio with 1,150. Common ratio was higher on the roof than the road. It is attributed to more rapid termination of effluents than the road. It also implies that sweeping deposits down by rainwaters is not very significant on the road.

## 4. CONCLUSION

Water quality management must include provisions for the control of water pollution associated with nonpoint sources and land uses. Despite arduous work, integrated sampling and precise examination were done and we found that urban nonpoint sources are seriously contaminated and are not being well managed. The local stream, Shingalcheon, and Shingal lake as well as ground water receive runoff from a vicinity of Shingal.

Since individual load of nonpoint sources during rainy periods is different according to the pattern of land use and the intensity of rainfall and duration of dry weather, it is very difficult to evaluate the precise individual load. From the investigation of the characteristics of conventional parameters of water pollution such as total suspended solids (SS), volatile solids (VS), chemical oxygen demand (COD), total nitrogen (T-N) and total phosphorous (T-P), and major inorganic elements, although nonpoint pollution is not limited to road runoff, it was found that the runoff from the road has been more contaminated than other sources.

The best plausible way to control the nonpoint sources is to apply the efficient sweeping programs to the highly contaminated road based on frequent systematic monitoring. If it is possible to settle down the suspended solids by detention systems in urban drainage, it also will reduce high load of pollutants over the short run. In the near future, the closer investigation of nonpoint sources for more various areas including industrial areas, commercial and residential areas will be made, which is believed to compensate the lack of valuable local data.

## REFERENCES

Bang K.W., Lee J.H. and Yu M.J. (1997). "A study on the runoff characteristics of nonpoint sources in small urban watersheds." *Journal of Korea Society of Water Quality,* Vol. 13, No. 1, pp. 79-99.

Delleur J.W. (1982). "Introduction to urban hydrology and stormwater management." *Urban stormwater hydrology,* Edited by David F. Kibler, American Geophysical Union Press, 2000 Florida Avenue, N. Y., Washington, D.C., pp. 1-34.

Hopke P.K. (1985). *Recepter modeling in environmental chemistry,* John Wiley & Sons, Inc., U.S.A., pp. 131.

Lynch J.A. and Corbett E.S. (1990). "Evaluation of best management practices for controlling nonpoint pollution from silvicultural perations." *Water Resources*

*Bulletins;* Vol. 26, No. 1, pp. 41-52.

National Institute of Env. Res. (1993). "Investigation upon the behavior of the pollutant outflow from the non-point sources." *National Institute of Env. Res.* pp. 1-59.

Novotny V. and Somlyody L. (1995). "Nonpoint pollution and urban stromwater management." *Water Quality Management Library*, Edited by Novotny V., Vol. 9, Technomic Pulishing Company, Inc., 851 New Holland Avenue, Box 3535, Lancaster, Pennsylvania, pp. 7-25.

Pisano W.C., Queiroz C., Aronson G.L. and Blanc F.C. (1981). "Procedures for estimating dry weather pollutant deposition in sewer systems." *Journal Water Pollution Control Federation*, Vol. 53, No. 11, pp. 1627-1636.

Schmidt S.D. and Spencer D.R. (1986). "The magnitude of improper waste discharge in an urban stormwater system." *Journal Water Pollution Control Federation,* Vol. 58, No. 7, pp. 744-748.

---

Jae Young Park, Young Min Jo, and Jong Min Oh, Institute for Environmental Science, Department of Environmental Science and Engineering, Kyung Hee University, Yongin, Kyunggi-Do, 449-701, Korea.
(e-mail: jmoh@nms.kyunghee.ac.kr)

(Received September 3, 1999; revised October 2, 1999; accepted November 1, 1999.)