An Estimation of NPS Pollutant Loads using the Correlation between Storm Water Runoff and Pollutant Discharge in a Small Urban Drainage Basin

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Abstract/Three purposes of this study are as follows: The first was the development of the extension method for the limited data observed in an urban drainage basin. The second was the analysis of the correlation between storm water runoff and NPS(non-point source) pollutant discharge. The last was the calculation of the monthly and annual specific NPS loads using the established correlation. The selected model was the SWMM(Storm Water Management Model) developed by the US EPA(Environmental Protection Agency). As a result of this study, the best correlation between storm water runoff and NPS pollutants discharge was produced by the nonlinear correlation between runoff rate(mm/hr) and specific loads rate(kg/ha) for all pollutants studied; SS, COD, BOD, and TN. The best correlation through the analysis based on evently total mass was made by the linear correlation between the specific accumulated runoff(mm) and the specific accumulated loads(kg/ha) for CASE1, and by the nonlinear correlation for CASE2. The NPS annual specific loads for the urban basin studied were 4,993 kg/ha/year for SS, 775 kg/ha/year for BOD, 3,094 kg/ha/year for COD, 257 kg/ha/year for TN, respectively. And the proportion of the NPS annual specific loads to the total annual specific loads were 41 % for SS, 13 % for BOD, 29 % for COD, and 21 % for TN.

1. Introduction

Hydrology and runoff phenomena are changed greatly due to the urbanization, and the characteristics of water pollution become entirely different from the nonurbanized area. Therefore, it seems urgent to select a model to study the characteristics of urban runoff and pollutant discharge for prevention of flood and water pollution in urban drainage basins. Recently, it has been known that plenty of pollutant was discharged into urban storm sewer and river due to the pollutant from nonpoint

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source(NPS) caused by rainfall. Since non point source pollutant is transported through basin runoff caused by rainfall, the simulation of pollutant loads through accurate runoff simulation should be exercised.

The Storm Water Management Model(SWMM) developed and maintained by the US Environmental Protection Agency(EPA) was used for the verification and simulation in this study. Both runoff and water quality can be simulated using SWMM model. In particular, the Runoff Block for the surface discharge and the Transport Block for the flow routing in the pipe were used.

Three purposes of this study are as follows: The first was the development of the extension method for the limited runoff and NPS pollutant loads data observed in a small urban drainage basin using SWMM model. The second was the suggestion of the method and procedure for the analysis of the correlation between storm water runoff and NPS pollutant discharge. The last was the calculation of the monthly and annual specific NPS loads using the established correlation. The importance of the correlation analysis between runoff and NPS pollutant loads based on the above three procedures in an arbitrary basin is that the appropriate correlation can be established for the limited data and that the control methods of NPS pollutant which affect water pollution to a great extent can be suggested. Also, this analysis will be helpful for the prediction of runoff and pollutant loads including NPS pollutant loads during design and management of detenetion pond and sewage treatment plant in an arbitrary basin.

2. The selection of study basin and the verification of SWMM model.

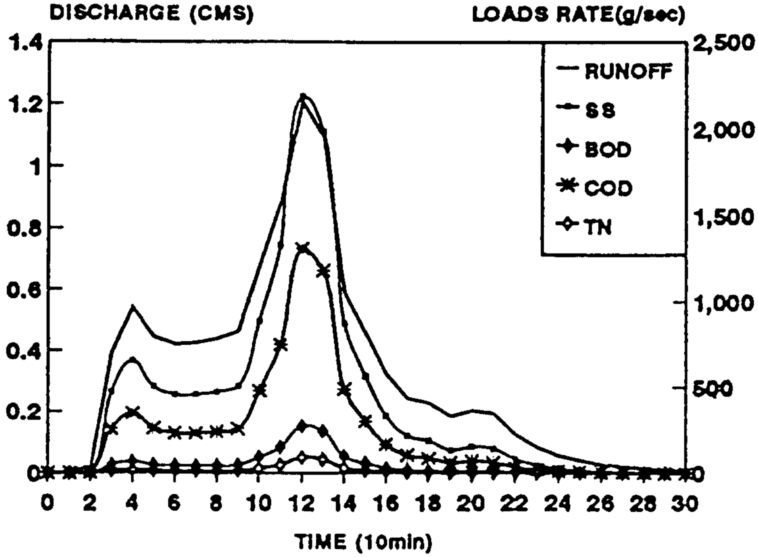
As a typical urban drainage basin, the Yongdu detention basin in Jeggi drainage outlet of Chunggye drainage district(Dongdaemun-Ku, Seoul) was selected for this study. This basin, which is bounded by the Jungrung stream on the East, Sungbuk stream on the West and Chunggye stream on the South, has an area of 43.47 ha and is composed of 55% for residential area, 25% for commercial area and 20% for road, respectively. In this study, the result that was calibrated and verified in the previous paper(A simulation of the runoff and the NPS pollutants discharge using SWMM model: Shin, Hyun Suk and Yoon, Yong Nam, 1993) was used with the runoff data caused by 4 rainfall events and the NPS water quality data caused by 2 rainfall events at the Yongdu detention basin.

3. The analysis of correlation between storm water runoff and NPS pollutant discharge

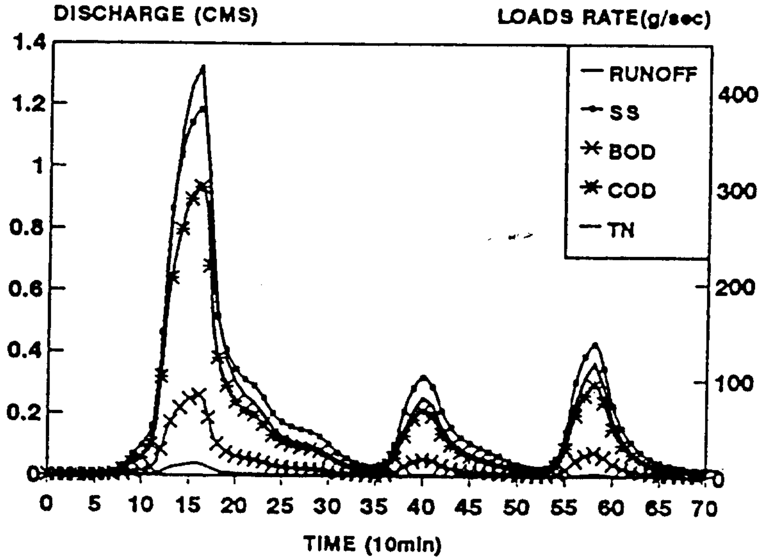
3.1 The extension of simulated rainfall event and data

For the simulation, rainfall events between '90 to '91 recorded by automatic rain recording gauge were obtained from the Dongdaemun district office and were classified as CASE1(long antecedent dry weather period)which includes 10 rainfall events and CASE2(short antecedent dry weather period) which includes 13 rainfall events.

Hourly data were extended through the simulation of the above real rainfall events using the verified SWMM model. The simulation was performed with time interval of 10 minutes, and runoff hydrograph and pollutant loads rate curve for each rainfall event were obtained at the same time. Fig. 3-1 shows the representative runoff hydrograph and pollutant loads rate curve for both cases obtained through the simulation.



FOR CASE 1. EVENT OF '90.8.14



FOR CASE 2. EVENT OF '90.7.11

Fig. 3-1 The representative runoff hydrograph and pollutant loads rate curve for each pollutant obtained through the simulation (CASE1 & CASE2)

3.2 The method of analysis

The methods of correlation analysis between runoff and pollutant loads, and the related regression equations are listed in the Table 3-1.

Table 3-1. The methods of correlation analysis and regression equation types between runoff and pollutant loads

Methods		Regression equation types
Analysis of hourly data for each event	Method T1	Linear correlation between runoff and concentration $C(t)=a+bQ(t)$ (mg/l) (cms)
	Method T2	Nonlinear correlation between runoff and concentration $C(t)=a[Q(t)]^b$ (mg/l) (cms)
	Method T3	Linear correlation between runoff and loads rate $L(t)=a+bQ(t)$ (g/sec) (cms)
	Method T4	Nonlinear correlation between specific runoff and specific loads rate $\left[\frac{L(t)}{A}\right]=a\left[\frac{Q(t)}{A}\right]^b$ (g/sec/ha) (mm/hr)
Analysis of total mass data for each event	Method M1	Linear correlation between specific accumulated runoff and specific accumulated loads $\left[\frac{\Sigma L}{A}\right]=a+b\left[\frac{\Sigma Q}{A}\right]$ (kg/ha) (mm)
	Method M2	Nonlinear correlation between specific accumulated runoff and specific accumulated loads $\left[\frac{\Sigma L}{A}\right]=a\left[\frac{\Sigma Q}{A}\right]^b$ (kg/ha) (mm)

The methods of analysis can be divided into two classes. The first is the analysis due to evently time history(Huber, 1988). The runoff and the pollutant loads(concentration, mg/l or loads rate, g/sec) from the runoff hydrograph and the water quality curve which were obtained from the simulation of the rainfall events for the CASE1(long antecedent dry weather period) and the CASE2 (short antecedent dry weather period) can be plotted on the x-y plane at the same time. The purposes of this analysis are to analyze the changing characteristics of pollutant loads according to the increase of runoff, and to get the best rating curve through regression analysis. The second is the analysis due to evently total mass(Kunimatz,1989). For each rainfall event, specific accumulated discharge(mm), i.e., total runoff volume(m3) divided by basin area(ha), and specific accumulated loads(kg/ha), i.e., total pollutant loads(kg) divided by basin area(ha) can be plotted on the x-y plane. The purposes of this analysis are to suggest the adequate regression equation between runoff and pollutant loads, and to obtain total pollutant loads according to the total rainfall amount for arbitrary rainfall events. The determined regression equations between runoff and pollutant loads will be used later to obtain monthly and annual pollutant loads for each pollutant.

3.3 The results of correlation analysis between runoff and pollutant loads

3.3.1 The results of regression analysis of evently hourly data

3.3.1.1 The case of long antecedent dry weather period(CASE1)

Regression analyses for SS, BOD, COD and TN were performed for both the CASE1 and the CASE2. Fig. 3-2, 3, 4, 5 show the SS and the COD as the representative of the results of regression analysis for each method. Also, regression coefficients a, b and determination coefficient R2(square of linear correlation coefficient) which were obtained from the regression analysis are listed in the Table 3-2 to decide the adaptability. Fig 3-2 ,which represents the results of the method T1, shows that the concentration according to the runoff was fairly dispersed and that the concentration was increased with runoff.

Fig. 3-3 shows the results of regression analysis according to the method T2. In this method, both runoff and concentration were taken on the logarithmic scale to analyze the data of the method T1 nonlinearly. It can be said that the correlation is improved and that the nonlinear method gives better result in the correlation analysis between runoff and concentration because the mean value of R2 for the method T2 was 0.9243 while the mean value of R2 for the method T1 was 0.8896.

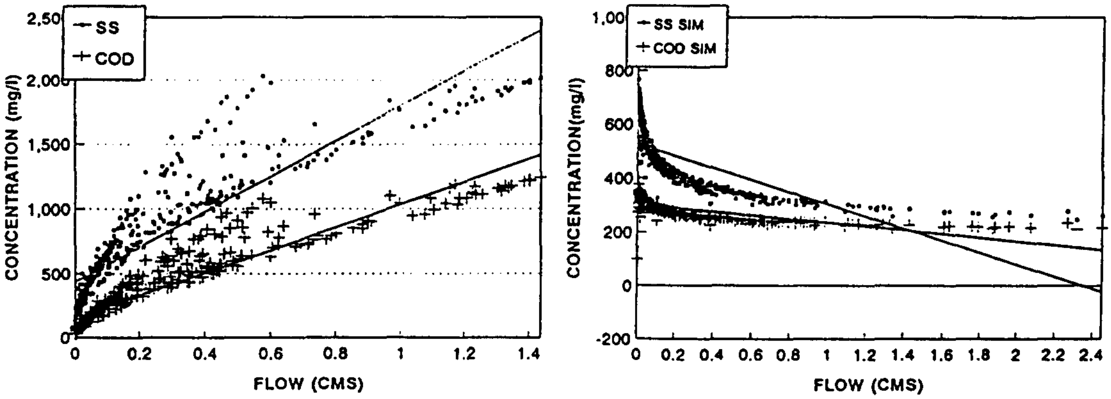


Fig. 3-2 The analysis of hourly data for each event based on the method T1 (CASE1 & CASE2, SS, COD)

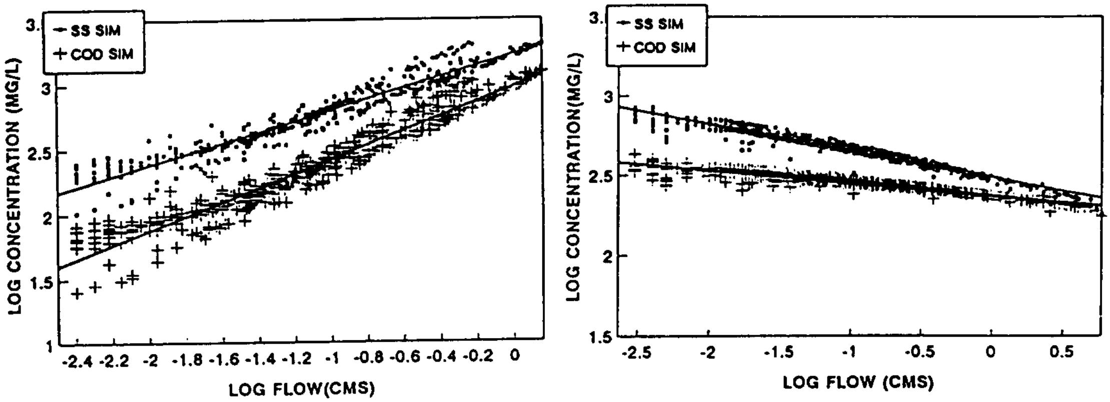


Fig. 3-3 The analysis of hourly data for each event based on the method T2 (CASE1 & CASE2, SS, COD)

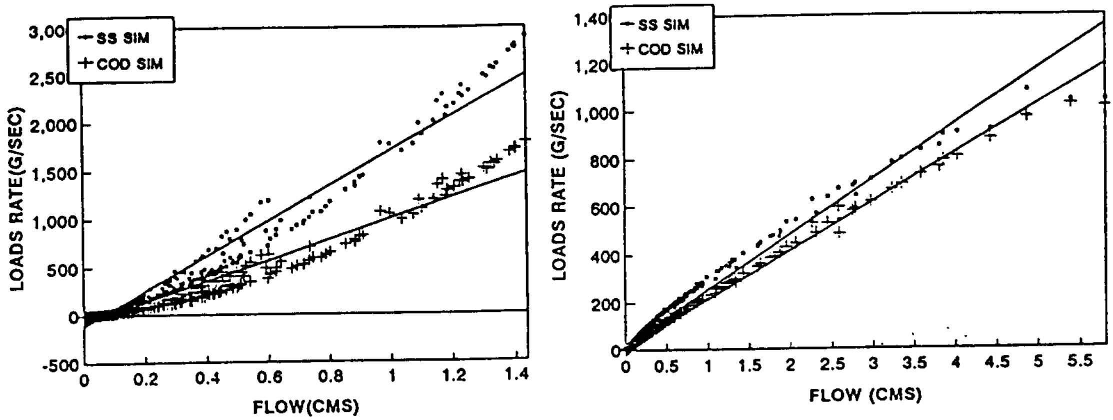


Fig. 3-4 The analysis of hourly data for each event based on the method T3 (CASE1 & CASE2, SS, COD)

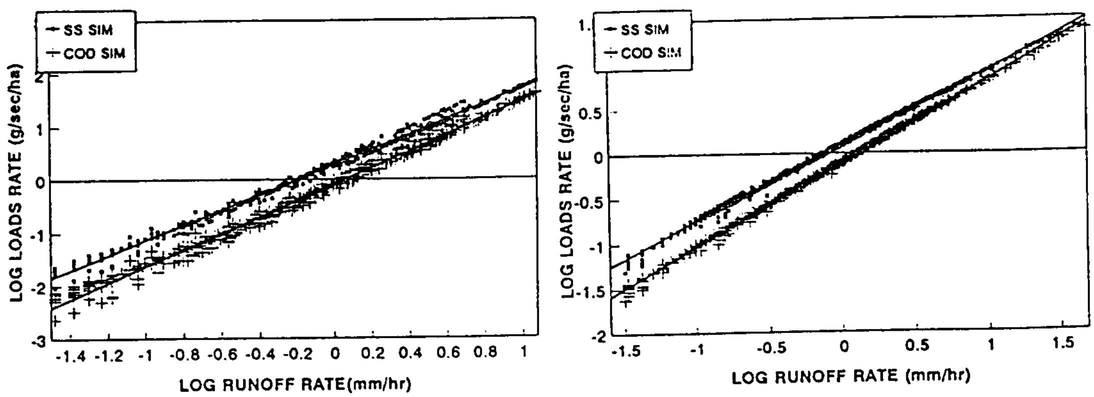


Fig. 3-5 The analysis of hourly data for each event based on the method T4 (CASE1 & CASE2, SS, COD)

The results of regression analysis between runoff and loads rate for the method T3 is shown in the Fig. 3-4. From this figure, it can be seen that the loop phenomenon of loads rate and large dispersion according to the increase of runoff. Also, the rate of increase of loads rate is larger than that of runoff. This phenomenon can be explained from the fact that the values of exponent b for all the pollutants were greater than 1.0 after the runoff and loads rate for the method T3 were taken on the logarithmic scale to do nonlinear regression analysis like the method T4.

Therefore, for the long antecedent dry weather period, pollutant loads discharge is increased as the runoff is increased due to the sufficient accumulation of pollutant before the precipitation. In the regression analysis between runoff and loads rate, the mean value of determination coefficient R2 was 0.9363 for the method T3(linear regression analysis) and was 0.9872 for the method T4

Table 3-2 The results of correlation analysis of hourly data for each event and case

(CASE 1)

Pollutants		Method T1	Method T2	Method T3	Method T4
SS	a	436.16	1614.09	-111.02	1.936
	b	1363.88	0.397	1814.73	1.395
	R^2	0.8096	0.9272	0.9524	0.9836
BOD	a	22.40	175.83	-18.09	0.142
	b	186.46	0.586	222.55	1.582
	R^2	0.9191	0.9317	0.9312	0.9899
COD	a	153.69	892.12	-80.64	0.832
	b	880.46	0.517	1079.58	1.514
	R^2	0.8883	0.9322	0.9435	0.9915
TN	a	5.01	53.89	-6.40	0.039
	b	62.59	0.637	73.52	1.632
	R^2	0.9411	0.9063	0.9184	0.9839
Mean R^2		0.8896	0.9243	0.9363	0.9872
Order of R^2		4	3	2	1

(CASE 2)

Pollutants		Method T1	Method T2	Method T3	Method T4
SS	a	498.77	307.42	1.215	
	b	-11.40	-0.169	0.840	
	R^2	0.3914	0.9674	0.9978	
BOD	a	73.38	64.92	1.58	0.198
	b	-5.29	-0.044	59.53	0.959
	R^2	0.4711	0.8087	0.9861	0.993
COD	a	295.50	235.56	9.89	0.773
	b	-36.31	-0.078	203.48	0.925
	R^2	0.3914	0.9093	0.9815	0.991
TN	a	10.74	9.64	0.198	0.029
	b	-0.65	-0.040	9.03	0.960
	R^2	0.4711	0.5112	0.9869	0.9967
Mean R^2		0.4312	0.7949	0.9804	0.9982
Order of R^2		4	3	2	1

(nonlinear regression analysis). Like the regression analysis between runoff and concentration for the method T1 and the method T2, nonlinear regression analysis between runoff and loads rate shows better correlation than that of linear regression analysis.

Table 3-2 also shows that the correlation between runoff and loads rate is better than the correlation between runoff and concentration. This result supports Wanielista's research(1978) that, in the analysis of NPS pollutant load caused by rainfall, it is reasonable to analyze using loads rate than concentration because pollutant loads is closely related with runoff.

3.3.1.2 The case of short antecedent dry weather period(CASE2)

The result for the method T1 is shown in the Fig. 3-2, and the concentration according to the runoff was fairly dispersed as in the CASE1, but the concentration was decreased as runoff was increased on the contrary to the CASE1.

Fig. 3-3 shows the regression analysis according to the method T2. To analyze the data for the method T1 nonlinearly, both runoff and concentration were taken on the logarithmic scale. The mean value of R2 for the method T2 was 0.7949 while the mean value of R2 for the method T1 was 0.4321. It can be said that the correlation is improved and that the nonlinear method gives better results in the correlation analysis between the runoff and concentration for the CASE2 too. Also, the negative slope of the regression line for the method T2 unlike the positive slope for the CASE1 explains the decrease of concentration according to the increase of runoff.

Fig. 3-4 shows the regression analysis between runoff and loads rate for the method T3. Unlike in the CASE1, the rate of increase of loads rate was smaller than that of runoff. This phenomenon can be explained from the fact that the values of exponent b for all the pollutants were less than 1.0 after the runoff and loads rate for the method T3 were taken on the logarithmic scale to do nonlinear regression analysis as in the method T4. Therefore, for the short antecedent dry weather period, the concentration and pollutant loads discharge rate was decreased as the runoff was increased.

In the regression analysis between runoff and loads rate, the average value of determination coefficient R2 was 0.9804 for the method T3(linear regression analysis) and was 0.9972 for the method T4(nonlinear regression analysis). Like the regression analysis between runoff and concentration for the method T1 and the method T2, nonlinear regression analysis between runoff and loads rate shows better correlation than that of linear regression analysis.

Fig. 3-5 shows that the correlation between runoff and loads rate is better than the correlation between runoff and concentration. Therefore, also in the CASE2, nonlinear regression equation between specific runoff and specific loads for the method T4 shows the best simulation results of discharge phenomenon for the runoff and NPS pollutant depending on time.

3.3.2 The result of analysis based on total mass

3.3.2.1 The case of long antecedent dry weather period(CASE1)

The results for both linear(method M1) and nonlinear(method M2) regression analysis between the specific accumulated runoff and the specific accumulated loads for each rainfall event are shown in the Fig. 3–6. The calculated regression coefficients a, b, and determination coefficient R2 for each method are listed in the Table 3–3. As the mean value of R2 was 0.9711 for the method M1 and was 0.9399 for the method M2 for all the pollutants, linear regression analysis based on the method M1 shows better correlation.

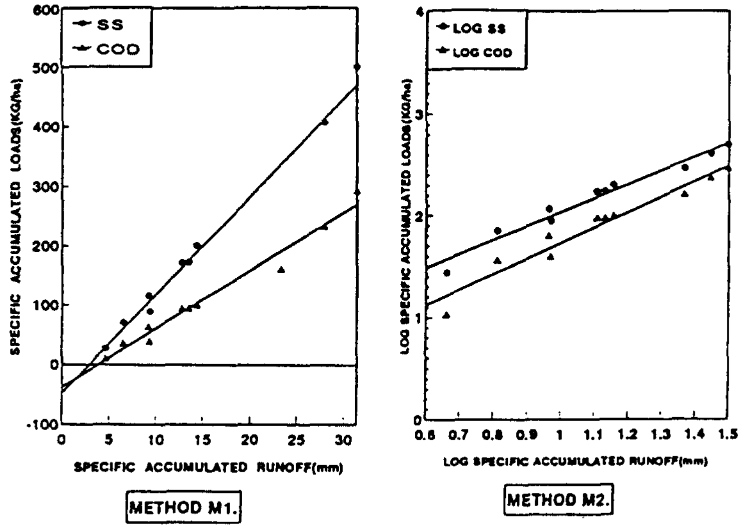


Fig. 3–6 The regression analysis of the total mass data for each event based on the method M1 and the method M2 (CASE1, SS, COD)

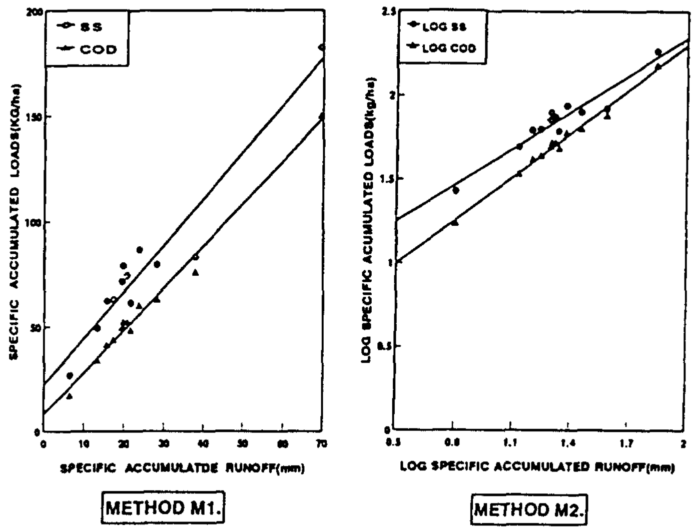


Fig. 3–7 The reqression analysis of the total mass data for each event based on the method M1 and the method M2 (CASE2, SS, COD)

3.3.2.2 The case of short antecedent dry weather period(CASE2)

The results for both linear(method M1) and nonlinear(method M2) regression analysis between the specific accumulated runoff and the specific accumulated loads for each rainfall event are shown in the Fig. 3-7. As in the CASE1, the calculated regression coefficients a, b, and determination coefficient R2 for each method are listed in the Table 3-3. As the mean value of R2 was 0.9757 for the method M1 and was 0.9845 for the method M2 for all the pollutants, nonlinear regression analysis

Table 3-3 The results of regression analysis of total amount data for each event and case

Pollutant	Methods	CASE1		CASE2	
		Method M1	Method M2	Method M1	Method M2
SS	a	-46.70	4.677	22.67	7.770
	b	16.52	1/366	2.21	0.724
	R^2	0.9821	0.9660	0.9225	0.9568
BOD	a	-8.47	0.245	1.37	0.840
	b	2.02	1.613	0.59	0.921
	R^2	0.9676	0.9321	0.9964	0.9962
COD	a	-36.69	1.625	8.45	3.695
	b	9.81	1.521	2.00	0.864
	R^2	0.9787	0.9448	0.9863	0.9875
TN	a	-3.06	0.059	0.17	0.121
	b	0.67	1.705	0.09	0.932
	R^2	0.9621	0.9179	0.9979	0.9975
Mean R^2		0.971	0.9399	0.9757	0.9845

based on the method M2 shows better correlation. In the regression analysis for all the pollutants, the coefficient b based on the method M2 was greater than 1.0 for the CASE1 but less than 1.0 for the CASE2. This phenomenon well explains the first-flush effect that the pollutant loads discharge for the long antecedent dry weather period(CASE1) is increased as the runoff is increased due to the sufficient accumulation of pollutants before the precipitation, and that the pollutant loads discharge for the short antecedent dry weather period(CASE2) is decreased as the runoff is increased because much pollutant loads was washed out by the antecedent precipitation.

4. The estimation of NPS pollutant loads from the study basin

In order to estimate the monthly and annual NPS pollutant loads, the method M1 for the CASE1, i.e., linear regression equation between the specific accumulated runoff and the specific accumulated loads, and the method M2 for the CASE2, i.e., nonlinear regression equation between the specific accumulated runoff and the specific accumulated loads were used for all the pollutants studied; SS, BOD, COD, and TN.

4.1 The method and procedure of estimation

In this study, two concepts were used to estimate the monthly and annual pollutant loads. First, monthly mean one event rainfall rather than annual mean one event rainfall was used considering that the rainfall characteristics are variant throughout the year and entirely different from month to month. Second, for the long(CASE1) and the short (CASE2) antecedent dry weather periods, the adequate regression equations obtained from the previous section were applied to improve the fact that the existing methods neglect the different characteristics of pollutant discharge between initial rainfall and subsequent rainfall using single regression equation for all the rainfall events indiscriminately. The procedure of estimation of NPS pollutant loads based on these concepts are as follows.

1) Derivation of regression equations for each pollutant. (CASE1:M1, CASE2:M2)
2) Analysis of rainfall: the estimation of the monthly and annual mean rainfall using the past rainfall data for the study basin. The classification of rainfall events corresponding to the CASE1 and the CASE2. The estimation of the monthly mean rainfall and the number of monthly mean rainfall events for each case.
3) Estimation of monthly mean one event runoff rate(mm), i.e., monthly mean runoff rate caused by one rainfall event for two cases. Monthly mean one event runoff rate(mm) = monthly mean rainfall(mm) * mean runoff rate/the number of rainfall event.
4) Estimation of monthly mean one event specific loads(kg/ha) substituting monthly mean one event runoff rate for regression equation.
5) Estimation of monthly specific loads for each case and pollutant Monthly specific loads(kg/ha/month) = monthly mean one event specific loads * the number of rainfall event for each month.
6) Estimation of annual specific loads for each case. Annual specific loads(kg/ha/year) = $\sum_{i=1}^{12}$ monthly specific loads(kg/ha/month)
7) Comparison and analysis between PS pollutant loads and NPS pollutant loads.

4.2 The analysis of rainfall

In this study, daily rainfall data at the Seoul meteorological station(No. 108, 1954-1987) were used to analyze the past rainfall. Monthly mean rainfall was calculated by adding the total daily rainfall for each month. To classify rainfall into the CASE1 and the CASE2, the following criteria were used after, from the daily rainfall data, eliminating the rainfall less than 3mm which does not significantly contribute to the runoff and the pollutant loads.

CASE1 : Runoff events for which antecedent dry weather period is greater than 4 days and antecedent rainfall is less than 5 mm.

CASE2 : Rainfall events that are not included in the CASE1 among the monthly rainfall events.

This classification is based on the study(Meister, 1981) that the accumulation of the urban pollutant is most sensitive to 5 days. The antecedent dry weather period which is the criterion of the CASE1 was selected as 4 days considering that the study basin is a considerably developed urban drainage basin(Wanielista, 1976). The number of rainfall events for each case were obtained by averaging the times of rainfall classified into the CASE1 and the CASE2 for each month. These results are listed in the Table 4-1.

Table 4-1 The results of rainfall data analysis (Seoul : 1954-1987)

	Monthly mean rainfall					Number of monthly mean rainfall event (>3mm)		
	Total	CASE1		CASE2		Total	CASE1	CASE2
Month	(mm)	(mm)	(%)	(mm)	(%)	Number	Number	Number
1	21.1	12.67	60.0	8.43	40.0	2.31	1.54	0.77
2	25.5	9.65	37.8	15.85	62.2	1.84	1.15	0.69
3	48.3	28.07	58.1	20.24	41.9	3.25	2.13	1.12
4	94.2	51.35	54.5	42.85	45.5	3.58	2.27	1.31
5	90.5	49.85	55.1	40.65	44.9	4.76	2.60	2.16
6	137.4	43.94	32.0	93.46	68.0	3.87	2.64	1.23
7	378.4	58.82	15.5	319.58	84.5	5.58	1.87	3.71
8	274.7	41.64	15.2	206.06	84.9	5.20	1.81	3.39
9	158.7	31.97	20.1	126.73	79.9	4.01	1.62	2.39
10	52.2	24.61	47.2	27.59	52.9	3.30	1.74	1.56
11	47.9	17.06	35.6	30.84	64.4	3.75	2.21	1.54
12	24.4	15.19	62.3	9.21	37.7	2.04	1.73	0.31
Total	1353.3	384.8	28.4	968.5	71.6	43.49	23.49	20.00

4.3 The estimation and analysis of monthly and annual specific loads for NPS pollutants

On the basis of the procedures described in the section 4.1, monthly specific loads(kg/ha/month) and annual specific loads(kg/ha/year) for each NPS pollutant discharge were calculated. The following analyses were performed using the above results: 1) Specific loads for NPS pollutant between the long and the short antecedent dry weather period. 2) The characteristics of NPS pollutant discharge for drought and flood period. 3) The material balance between annual specific NPS loads and PS loads.

4.3.1 The calculation of the monthly and annual specific NPS loads for each case

In the calculation of the monthly and annual specific NPS loads for each case, the rainfall event for the CASE1 has large rainfall loss because of surface loss and infiltration, and the rainfall event for the CASE2 has rather small rainfall loss. Therefore, in the mean discharge rate for the procedure described in the section 4.1, it is unreasonable to apply mean discharge rate of the CASE1 and the CASE2 equally. Therefore, the average values of runoff rates resulted from the simulation of rainfall event described in the section 3.1 were used for the runoff rates of the CASE1 and the CASE2. The mean runoff rates were 0.643 for the CASE1 and 0.726 for the CASE2, respectively.

The monthly and annual specific NPS loads are listed in the Table 4-2.

Table 4-2 Monthly and annual specific NPS pollutant loads (Unit: kg/ha/month)

Pollutant	SS		BOD		COD		TN	
Month	CASE1	CASE2	CASE1	CASE2	CASE1	CASE2	CASE1	CASE2
1	62.71	26.84	4.89	4.37	23.03	17.06	0.75	1.39
2	48.78	41.12	3.91	7.74	18.36	29.00	5.64	1.79
3	198.73	56.10	21.67	10.07	98.36	38.26	5.58	7.07
4	439.42	100.84	53.41	20.35	239.99	74.72	15.17	18.21
5	403.86	111.43	47.73	20.16	215.00	76.42	13.24	16.23
6	345.35	174.29	39.78	41.52	179.53	145.31	10.84	17.10
7	537.87	575.71	67.36	140.57	301.86	488.49	19.61	40.80
8	357.87	408.68	43.58	93.16	195.81	330.24	12.40	26.39
9	263.86	261.03	31.49	57.93	141.74	206.94	8.81	17.50
10	180.09	76.95	20.07	13.76	90.88	52.31	5.28	7.31
11	78.02	83.08	5.42	15.22	25.94	37.47	0.59	2.85
12	80.56	22.26	6.83	4.41	31.87	16.27	1.25	1.91
Total	2997.12	1938.33	346.14	429.26	1562.37	1512.49	99.16	158.55
(kg/ha/yr)	4935.45		775.40		3074.86		257.71	

4.3.2 The comparison of the specific loads between long and short antecedent dry weather period

For the rainfall and each pollutant, the ratio of the CASE1 to the CASE2 is shown in Fig. 4-1.

The calculated annual mean specific loads(kg/ha/mm) per unit rainfall (i.e., annual specific loads (kg/ha) divided by annual mean rainfall(mm) corresponding to each case) for each pollutant are listed in the Table 4-3. In order to compare the two cases, the annual mean specific loads per unit rainfall for the CASE1 was divided by the annual mean specific loads per unit rainfall for the CASE2. The result shows that the discharge of the NPS pollutant loads for the CASE1 was 3.9 times for SS, 2 times for BOD, 2.6 times for COD and 1.6 times for TN larger than that of the CASE2 for the same rainfall.

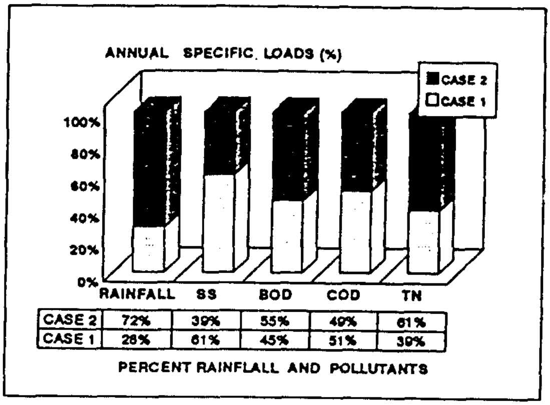


Fig. 4-1 The comparison between the annual mean rainfall and the annual specific loads for each case

Table 4-3 Annual mean specific loads for unit rainfall (Unit: kg/ha/mm)

CASE/NPS	SS	BOD	COD	TN
CASE1	7.78	0.90	4.06	0.26
CASE2	2.00	0.44	1.58	0.16
CASE1/CASE2	3.89	2.50	2.57	1.63

4.3.3 The comparison of annual specific loads during drought and flood period

To compare the annual specific loads during drought and flood period, the summations of monthly specific loads for flood period(July and August) and for drought period(other months) were calculated for each case, and the proportions of the results are listed in the Table 4-4. The result explains that the NPS pollutant discharge caused by initial rainfall which has long antecedent dry weather period during the drought period occupies more than 60% of pollutant discharge for the total rainfall period. Therefore, to treat NPS pollutant reasonably, a scheme which can increase treatment efficiency of pollutant at the initial rainfall should be considered.

Table 4-4 The comparison of NPS pollutant loads during the flood and the drought period (Unit: kg/ha/year)

Month/Pollutant		SS	BOD	COD	TN
July, August	CASE1	895.2(48%)	110.9(32%)	497.7(38%)	40.8(39%)
	CASE2	984.4(52%)	233.7(68%)	818.7(62%)	67.2(61%)
	Total	1879.6	344.7	1316.4	108.0
September -June	CASE1	2099.4(69%)	235.2(55%)	1064.7(60%)	58.2(40%)
	CASE2	954.0(31%)	195.5(45%)	713.8(40%)	89.8(60%)
	Total	3053.4	430.7	1778.5	148.0

4.3.4 The comparison between annual specific NPS loads and point source(PS) loads

The calculated annual specific NPS loads and PS loads are listed in the Table 4-5. The annual specific PS load was estimated from the mean loads rate(g/sec) that was observed during non rainfall period under the assumption of constant PS pollutant discharge through the year. Fig. 4-2 explains the rate of contribution of annual specific NPS loads for each pollutant to the total pollutant. Therefore, the pollution caused by the NPS pollutant that flows in the detention basin affects considerably on the pollution at the tributary and stream, and in order to decrease the pollution in the stream the treatment of NPS pollutant during rainfall seems necessary.

Table 4-5 The comparison of annual specfic pollutant loads between NPS ans PS (Unit: kg/ha/year)

Pollutants	SS	BOD	COD	TN
NPS	4933	775	3090	257
PS	7182	5376	7467	943
Annual total	12115	6151	10557	1200

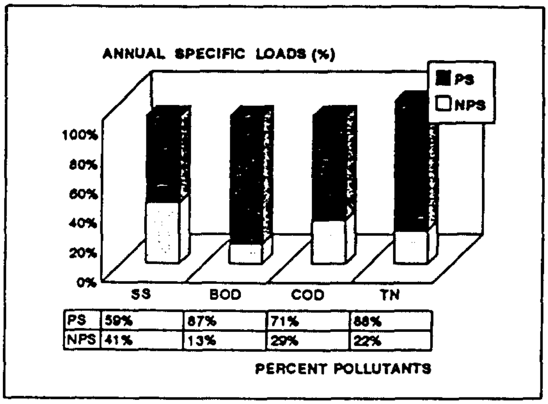


Fig. 4-2 The mass balance of the annual specific loads between NPS and PS

5. Conclusions

Actually, it is economically difficult to measure the runoff and pollutant loads continuously to estimate the NPS loads in the urban drainage basin. The characteristics of NPS pollutant discharge differ entirely, and the annual loads for each pollutant differ greatly due to the difference of the urbanization history and the land uses even in the same urban drainage basin. Therefore, to overcome these contradictions, the correlation between runoff and pollutant loads for several study basins and a scheme which enables to estimate monthly and annual NPS loads for each pollutant quantitatively using low cost are suggested in this study with the following nine application steps.

The procedure to apply the method suggested in this study is follows:

1) The measurement of runoff and pollutant loads(concentration or loads rate) for the study basin. Data collection for the long(CASE1) and the short(CASE2) antecedent dry weather period to consider the first-flush effect for the NPS pollutant.
2) The verification of SWMM model for runoff and loads rates for each case using the data obtained from the step 1.
3) The collection of observed rainfall events for each case to simulate many times.
4) The acquisition of many runoff hydrographs and loads rate curves for each case applying rainfall events of the step 3 into the SWMM model verified in the step 2.
5) The analysis of NPS pollutant discharge characteristics based on the analysis of hourly data for each rainfall event.
6) The decision of adequate regression equation between specific accumulated loads and specific accumulated runoff based on the analysis of total mass data for each rainfall event.
7) The decision of monthly mean rainfall and the number of monthly mean rainfall event for each case through the analysis of daily rainfall data for the basin.
8) The estimation of the monthly and annual specific NPS loads for each pollutant applying the an-

alyzed rainfall data in the step 7 into the regression equations obtained in the step 6.

9) The calculation of mass balance of specific PS loads and NPS loads for each pollutant.

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