MANAGEMENT OF STORM RUNOFF TO REDUCE NON-POINT POLLUTION

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ABSTRACT

It is required an integrated management for the reduction of rainfall runoff, non-point pollution, and flood damage *etc*. in order to improve water environment of urban area. This study focuses on the reduction method of flood damage due to sudden rainfall runoff as well as on the reduction of non-point pollutant efflux through the control of rainfall runoff in the urban area. Through the research on the efflux characteristics of non-point pollutant, it is proposed to reduce rainfall runoff as well as to reduce non-point pollutant on the basis of the characteristics of non-point pollutant and rainfall runoff.

KEYWORDS:Stormwater management; rainfall runoff; nonpoint pollution; land use; flood damage; water quality

INTRODUCTION

The characteristics of rainfall runoff are changed due to the increase of non-permeability in the course of urbanization. Sudden rainfall runoff makes flood damage increased in a view of water quantity and the draining of various pollutants with rainfall runoff to water system makes water quality decreased. As non-permeable pavement is specially increased, both peak efflux and the moving momentum of non-point pollutants are increased. An integrated control in both water quality and quantity is required. Therefore, the purpose of the study is to reduce flood damage due to sudden rainfall runoff through strengthening maintenance function of water basin as well as to reduce the burden of non-point pollution through the control of rainfall runoff in urban area. In consideration of both the relation of rainfall runoff by land use with the drain of non-point pollutants and the reduction of non-point pollution, it will be made to improve policy for the introduction of management facility of rainfall runoff. The policy deals with some topics such as the relation of non-point pollution efflux by land use with rainfall runoff, the analysis about reduction facility of rainfall runoff for water quality improvement, and the policy improvement for the introduction of the reduction facility of rainfall runoff in consideration of the reduction of non-point pollution.

SITES AND MEASUREMENTS

Sampling sites

To study the efflux characteristics of non-point pollutants by land use in rainfall, urban area is classified as total 6 land uses such as high-density apartment area, single residential area, commercial area, industrial area, motorway, and parking lot. Total 12 points by 2 points at each land use are selected. Survey location is selected at Bundang-Gu, Seongnam-Si, Kyonggi-Do. Bundang-Gu is installed with tributary drain conduit, which can exclude efflux effect in rainfall, and has relatively manifest land use. Efflux characteristics of non-point pollutants due to rainfall by land use can be comparatively easily analyzed at Bundang-Gu.

Table 1. Characteristics of the two sampling points

Land Use		Basin Area(m^2)	Non-permeability(%)	Comments
Point I	Apartment area	5,556.3	80	Household : 200
	Residential area	7,208.6	95	Household : 154
	Business area	12,257.1	98	Store : 50
	Industrial area	41,44.2	96	Employee : 920
	Motorway	4,880.6	100	Lane : 6
	Parking lot	400.6	99	Capacity : 369
Point II	Apartment area	883.8	80	Household : 92
	Residential area	3,834.6	90	Household : 133
	Business area	1,221.9	100	Store : 41
	Industrial area	37,259.1	96	Factory : 6, Employee : 1160
	Motorway	2,561.4	100	Lane : 6, crossroad
	Parking lot	7,540	95	Capacity : 157

Measurements

To study efflux characteristics of non-point pollutants in rainfall runoff, event mean concentration (EMC)(Vladimir and Harvey. 1994) and site mean concentration (SMC) by land use are calculated. The following are water quality items and sampling time for the water quality analysis of rainfall runoff.

Sampling: flexibly sample according to field rainfall condition in rainfall, early 0 minutes, 15 minutes, 30 minutes, 1 hour, 2 hours, 4 hours.
Analysis items: biochemical oxygen demand(BOD), chemical oxygen demand(COD), suspended solid(SS), total nitrogen(T-N), total phosphate(T-P), heavy metals(Zn, Cd, Pb, Cu), water temperature, rainfall volume, drain flux
To study reservoir effect, acryl container in the size of laboratory is used. Its size is 29×29×35(L×W×H) cm^3 and the sampling points are each 4.5cm, 15cm, 30cm from the floor. Reservoir experiment of rainfall runoff is performed with rainfall runoff of total 3 land uses (residential, business, motorway). Rainfall runoff is contained in reservoir and sampled at top and middle points of the reservoir at the interval of 30 minutes, 1 hour, 2 hours, 4 hours, 8 hours, 12 hours, 24 hours, 48 hours and analyzed water quality.

RESULTS AND DISCUSSION

Water Quality Characteristics of Rainfall Runoff by Land Use

Efflux concentration in most pollutants is increasing at initial rainfall runoff. Efflux characteristics by land use do not show meaningful difference. To study efflux characteristics of pollutants in rainfall, the burden ratio of cumulative pollution is used. Method to express the burden ratio of cumulative pollution is to show a graph, of which x-axis is a ratio($Q(t)/\sum Q(t)$) of flux Q(t) to cumulative flux $\sum Q(t)$ at discrete time interval and y-axis is a ratio($L(t)/\sum L(t)$) of pollution burden L(t) to cumulative pollution burden $\sum L(t)$ at discrete time interval. If the slope of the graph is larger than 1, initial efflux is strong and vice versa. Insoluble particulate is easily drained in initial rainfall and the slope is also larger than 1. Soluble material is uniformly drained in rainfall and the slope approaches to 1. The following figure(area 1, rainfall 2) shows the ratio of pollutant efflux due to rainfall efflux to rainfall run off.

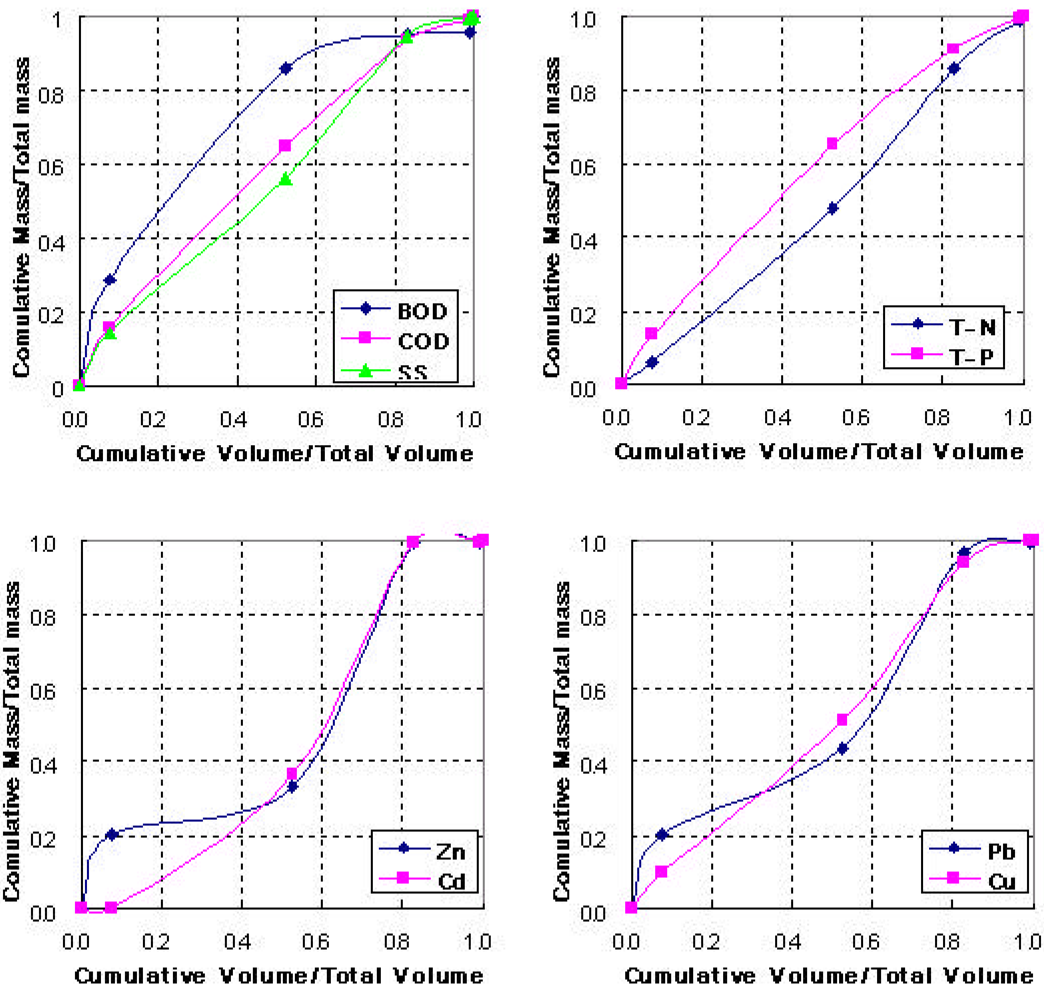

***Figure 1.** Runoff characteristics of cumulative non-point pollutant to cumulative run off*

In the figure, BOD, COD, and SS show initial efflux phenomena for many pollutants to be drained in initial rainfall. In nutrients, T-N shows initial efflux phenomena for many pollutants to be drained in initial rainfall and T-P shows relatively uniform efflux characteristics.

Event Mean Concentration & Site Mean Concentration by Land Use

To study efflux characteristics of non-point pollutant in rainfall runoff, both event mean concentration (EMC)and site mean concentration (SMC) by land use are calculated. The following Table shows SMC and coefficient of variance (COV) by land use.

Table 2. Site mean concentration (SMC) and coefficient of variance(COV) by land use

Classification		BOD	COD	SS	T-N	T-P	Cu	Zn	Cd	Pb
High density apartment area	SMC	6.1	15.9	59.6	3.26	0.31	0.038	0.013	0.054	0.037
	COV	0.60	0.58	0.81	0.81	0.35	0.86	0.88	0.70	0.18
Single residential area	SMC	9.0	38.5	32.5	5.00	0.24	0.032	0.022	0.066	0.071
	COV	0.24	0.54	0.75	0.49	0.27	1.08	1.34	1.03	0.33
Business area	SMC	8.1	57.8	52.5	9.62	0.39	0.046	0.025	0.067	0.031
	COV	0.46	0.85	0.71	0.57	0.83	0.66	1.55	1.15	1.09
Industrial area	SMC	12.3	61.3	67.6	7.35	0.40	0.080	0.009	0.078	0.054
	COV	0.17	0.28	0.57	0.52	0.25	0.78	0.90	0.26	0.32
Motorway	SMC	12.1	67.7	126.6	7.56	0.48	0.141	0.031	0.111	0.097
	COV	0.46	0.42	0.40	0.54	0.83	1.30	1.02	0.69	0.36
Parking lot	SMC	5.3	48.0	22.7	3.39	0.09	0.043	0.045	0.093	0.030
	COV	0.67	0.77	0.72	0.75	0.38	1.09	1.17	0.92	0.73
Comment) COV(coefficient of variance) = standard variance/mean										

The following figure shows SMC by land use and the following introduces SMC characteristics.

- BOD, COD, SS : BOD's SMC shows comparative low value in the range of 5.3   12.1mg/L and do not show large difference by land use. The SMCs of COD and SS show the range of 115.9   67.7mg/L and 22.7   126.6mg/L. Motorway shows the largest concentration.

- T-N, T-P : T-N's SMC shows the range of 3.26   9.62mg/L and expresses the largest concentration in commercial area. This may be due to the food garbage from many restaurants in commercial area. T-P's SMC shows the range 0.09   0.48mg/L.

- Heavy metals(Zn, Cd, Pb, Cu) : SMCs of heavy metals Zn, Cd, Pb, and Cu show the range of each 0.043   0.141mg/L, 0.009   0.045mg/L, 0.054   0.111mg/L, and 0.030   0.097mg/L. Heavy metals show relatively high concentration at motorway and parking lot. This may be due to the operation of mobile.

In the efflux characteristics of non-point pollutants due to rainfall runoff, BOD, COD, SS, T-N, and T-P show first flushing effect, which shows relatively high concentration in initial rainfall runoff, and heavy metals(Zn, Cd, Pb, Cu) do not show the relevance between first-flushing and rainfall runoff. In SMC of non-point pollutant by land use, BOD's SMC shows relatively low concentration in the range of 5.3 - 12.1mg/L and does not show large relevance by land use. The SMCs of COD and SS show the range of 115.9 - 67.7mg/L and 22.7-126.6mg/L. Motorway shows the largest concentration. T-N's SMC shows the range of 3.26 - 9.62mg/L and expresses the largest concentration in commercial area. T-P's SMC shows the range of 0.09-0.48mg/L. Heavy metals(Zn, Cd, Pb, Cu) show relatively high concentration at motorway and parking lot. This may be due to the operation of mobile.

Analysis of the reduction of non-point pollutant due to undercurrent basin

Initial SS concentration of rainfall runoff at residential area is 165.0mg/L and is reduced to 37.0mg/L at discontinuance point after 24 hours settlement. Initial COD concentration is 70.2mg/L and is reduced to 25.7mg/L at discontinuance point after 24 hours settlement.

Initial SS concentration in commercial area is 89.0mg/L and is reduced to 12.0mg/L at discontinuance point after 24 hours settlement. Initial COD concentration is 157.8mg/L and is reduced to 42.0mg/L at discontinuance point after 24 hours settlement.

Initial SS concentration of rainfall runoff at motorway is 97.0mg/L and is reduced to 8.0mg/L at discontinuance point after 24 hours settlement. Initial COD concentration is 149.0mg/L and is reduced to 30.3mg/L at discontinuance point after 24 hours settlement.

Generally, settlement characteristics of rainfall runoff are good. It is possible that settlement for only 12 hours remove more than 60% of both COD and SS. When water reservoir of pumping station is used as water treatment facility, rainfall runoff must be stored and settled for at least 12 hours and drained from the top of the reservoir. Muddy water at its bottom must be treated and drained.

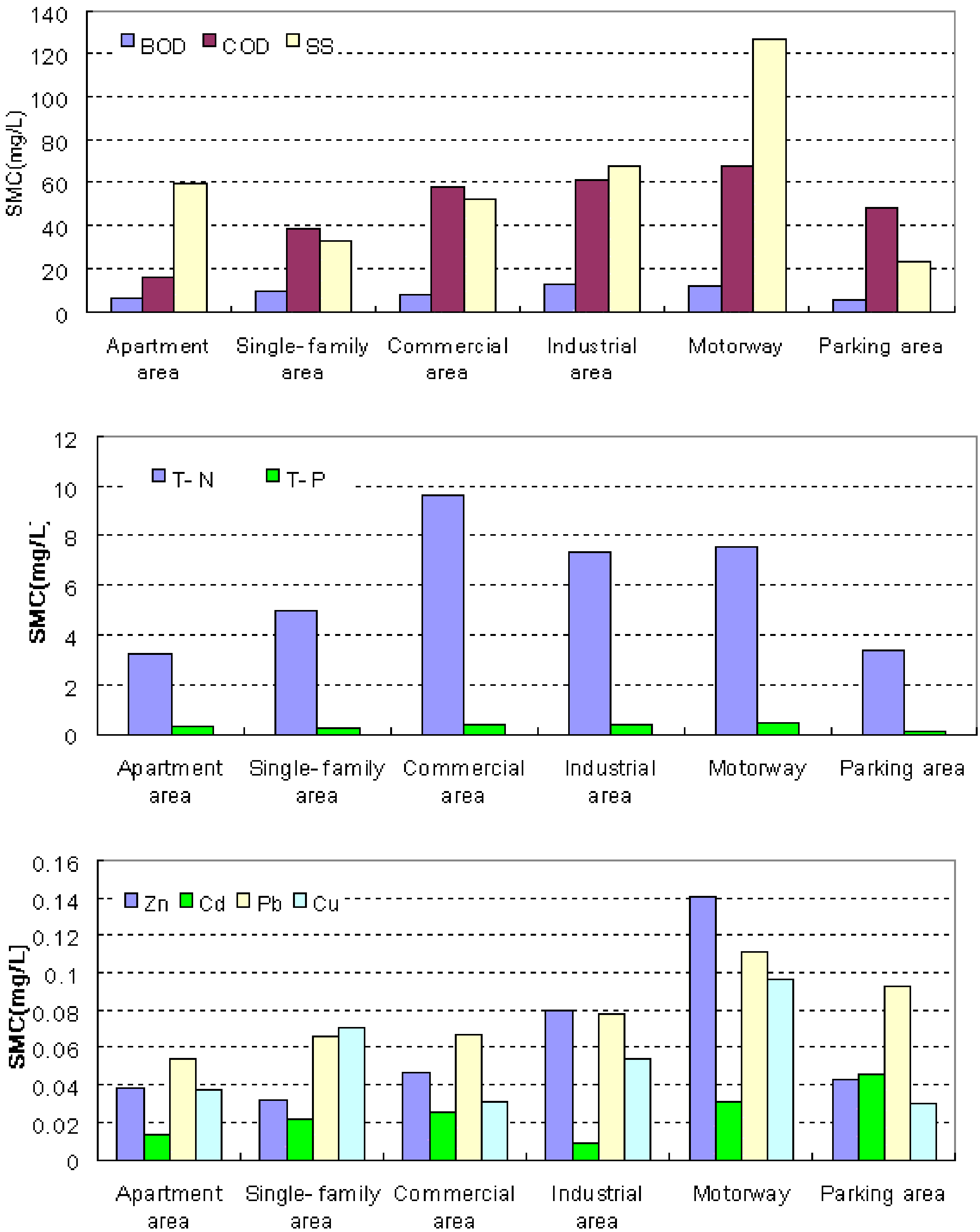

Figure 2. *Comparison of SMC according to the use of land*

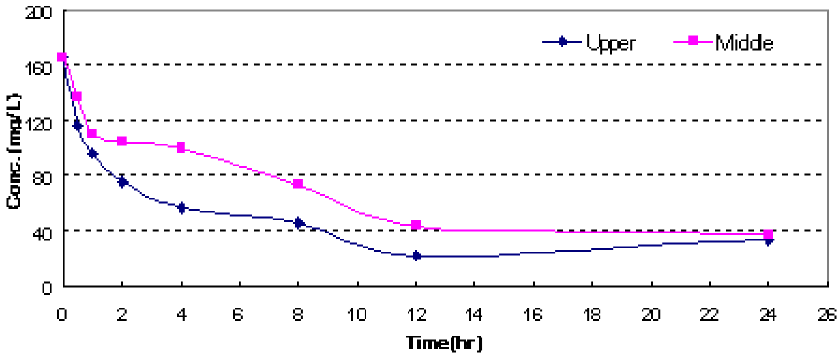

Figure 3. *Settlement characteristics of SS of storm runoff (residential area).*

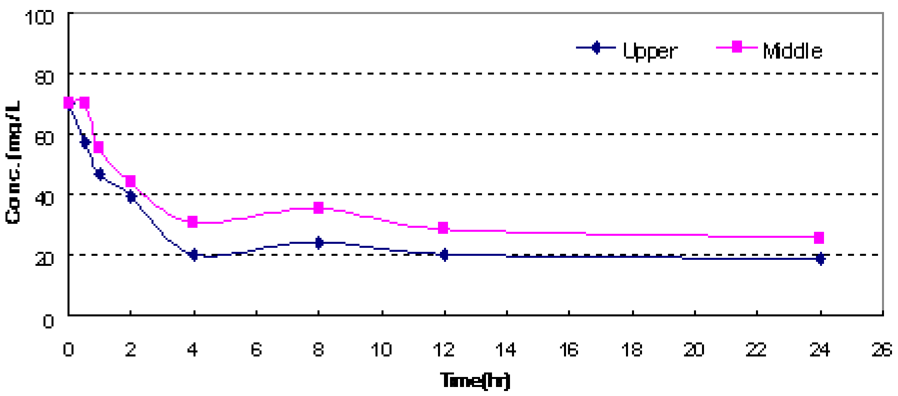

Figure 4*. Settlement characteristics of COD of storm runoff (residential area)*

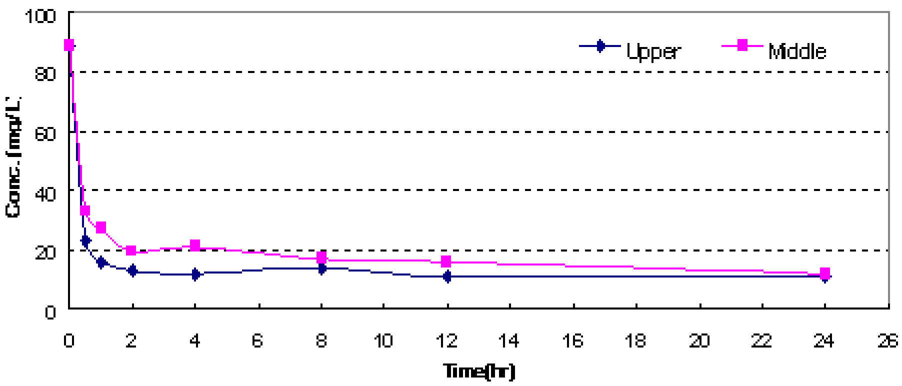

Figure 5. *Settlement characteristics of SS of storm runoff (commercial area)*

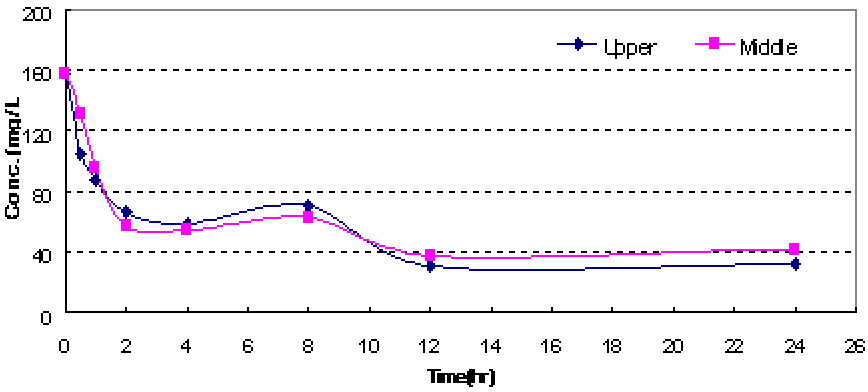

Figure 6. *Settlement characteristics of COD of storm runoff (commercial area)*

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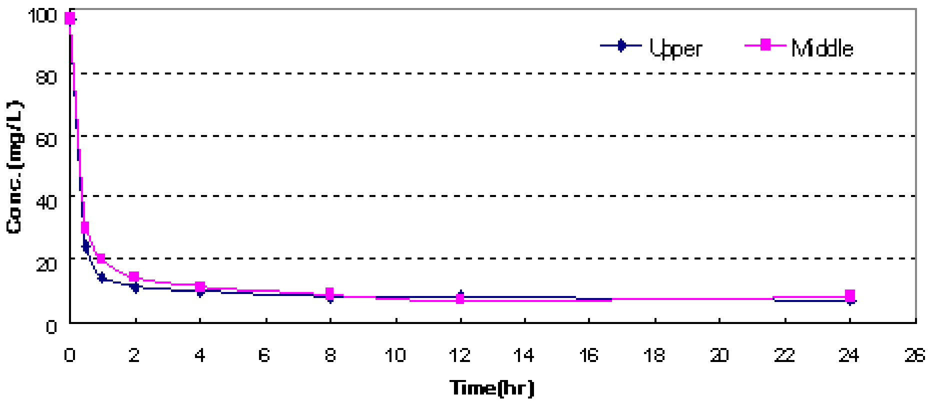

Figure 7. *Settlement characteristics of SS of storm runoff (Motorway)*

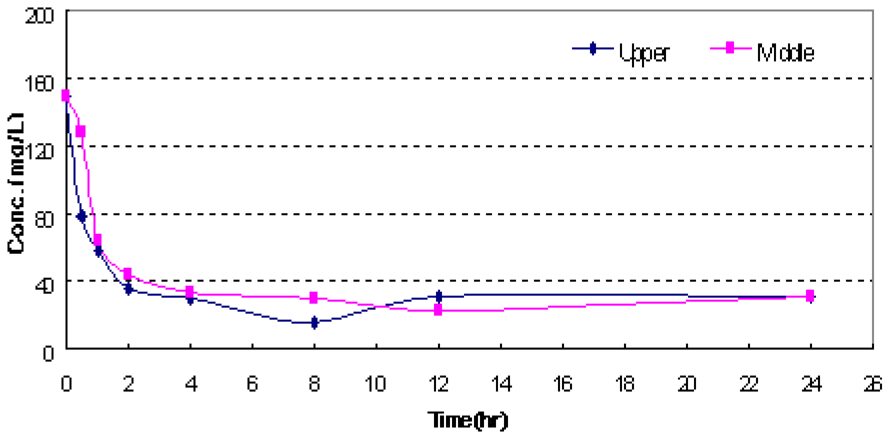

Figure 8. *Settlement characteristics of COD of storm runoff (Motorway)*

Reduction analysis of rainfall runoff and non-point pollutant by infiltration receiving box

Infiltration receiving box has a structure, of which bottom is packed by sand and rubble and pierced to infiltrate water, and is consisted of 10cm sand and 90cm rubble layer. Infiltration receiving box has been installed to prevent the inundation damage of heavy rain in urban area. It can be recently considered to reduce non-point pollutant by the underground infiltration of rainfall runoff.(ASCE, 1998). While rainfall runoff flew into infiltration receiving box passes infiltration layer and ground layer, its contaminant is removed and replaced with underground water.

As rainfall is increased, the runoff of general receiving box is also linearly increased. However, the runoff of infiltration receiving box is less reduced than the runoff of general receiving box. Average runoff reduction at each point is 73.32% in Sungnam, 75.1% in Osan, or 73.4% in Cheongju.

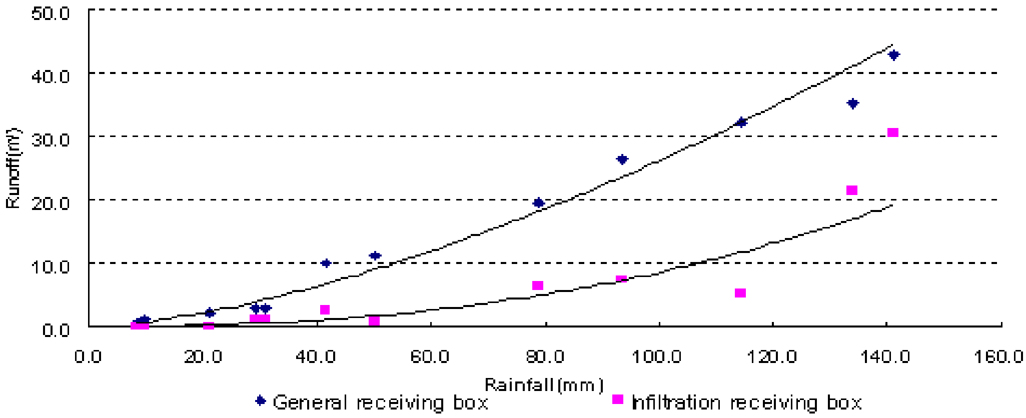

Figure 9. *Runoff characteristics of general receiving box and infiltration receiving box (Sungnam)*

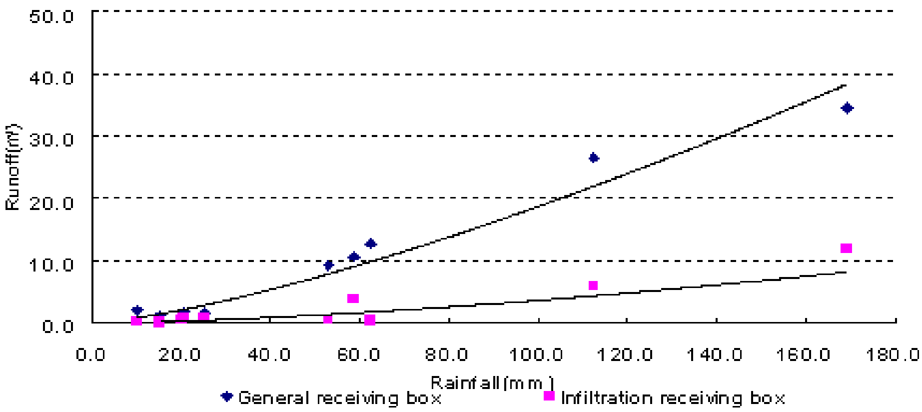

Figure 10. *Runoff characteristics of general receiving box and infiltration receiving box (Osan)*

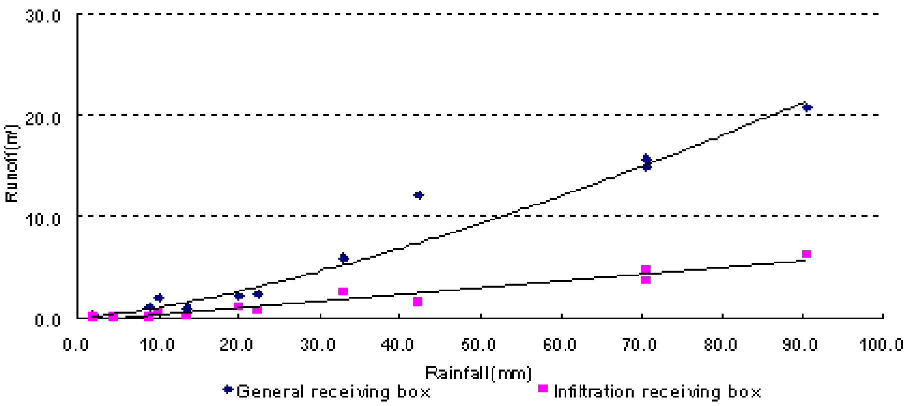

***Figure 11**. Runoff characteristics of general receiving box and infiltration receiving box (CheongJu)*

To study the effect of infiltration receiving box in entire drainage region on runoff reduction, it is considered that infiltration receiving box is applied to the road of entire drainage region and its effect on the reduction of rainfall runoff is checked. Experimental area is CheongJu. Runoff is used to analyze 70.5mm rainfall of July 21, 2001 by ILLUDAS model. In the simulation result of rainfall runoff, the reduction of total runoff is about 18.5% and the reduction of peak flow is about 16.6%. Considered with the large concentration of non-point pollutant in initial rainfall runoff, the installation of infiltration receiving box makes the burden of non-point pollution lessened by more than 18.5%.

Table. 3. Peak flow reduction effect by installing infiltration receiving box

Rainfall (mm)	General Receiving Box		Infiltration Receiving Box		Reduction Effect	
	Runoff (m^3)	Peak Flow (cms)	Runoff (m^3)	Peak Flow (cms)	Runoff (%)	Peak Flow (%)
70.5	150526.2	33.69	122817.6	28.09	18.4	16.6

CONCLUSIONS

Since the characteristic of pollutant runoff by rainfall shows relatively high concentration in early runoff. More than 80% of the entire rainfall are 20mm and below in Korea(MOCT, 2001), the storm runoff treatment facilities for the reduction of non-point pollution may be designed to cover approximately 20mm rainfall. It will be able to treat more than 80% of the entire rainfall and contribute to reduce considerably the non-point pollution burden(Choi and Shin, 2002). However, when establishing the storm runoff treatment facilities in certain area, the geomorphologic peculiarities and hydrological characteristics as well as the climate and applicable technologies must be taken into consideration when determining the scale of the facilities. Moreover, the peculiarity of Korean climate, which has more than 70% of ra infall in the rainy spell in summer, shall also be considered when selecting the storm runoff treatment technology and designing the facilities.

There are many types of storm runoff treatment facilities applicable to each local peculiarity. In Korea, where the use of land is limited, the size of land required for the treatment facilities shall be the main consideration in selecting the location. Generally, the urban areas where wide area is not usually unavailable, adopt infiltration facilities that occupy relatively small area. Especially, the appropriate measures are needed to enable the control of non-point pollution by supplementing existing manhole and to improve the rainwater detention pond to make it possible to treat the early rainwater non-point pollution. The installation of apparatus type facilities such as Stormceptor, Stormfilter and Swirl/Vertex(John C. Clausen. 2002). needs sufficient preliminary study in terms of their effectiveness in peculiar climate and geographical features of Korea.

Moreover, increased impermeable rate accompanied by urbanization changed the characteristics of storm runoff. It added to the damage from flood due to rapid storm runoff seen from the water volume aspect. Seen from the aspect of water quality, it caused the water quality to be deteriorated with the runoff of various polluting materials into the water system along with the storm runoff. Therefore, immediate action shall be taken to properly control the storm runoff to reduce the risk of flood by rapid storm runoff and to improve the water quality.

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