

ORIGINAL ARTICLE

## Contribution of Non-Point Pollution to Water Quality and Runoff Characteristics from Agricultural Area of the Upstream Watersheds of Lake Chinyang

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### Abstract

In this study, non-point source(NPS) contribution was investigated based on flow rates and water qualities of streams into the lake during rainfall events. Event mean concentration(EMC) and the pollution loads were calculated to establish a database for NPS control measurement in the survey area, and so on. The runoff characteristics of NPS were investigated and estimated on the basis of the ratio of an agricultural to forest area in the stream of sub-catch basin during rainfall events. Non-point source pollution loads were also calculated to establish a database for NPS control measure in the upstream lake Chinyang. At a rainfall event, BOD concentrations rise sharply at the early peak time of runoff, however, peaks of TSS concentration were observed at the similar time of peak flow. This was a phenomenon shown at the watersheds caused by forest and geological types. The discharged EMC range was 2.9-4.8 mg/L in terms of BOD. The discharged EMC range was 6.2-8.2 mg/L in terms of SS. The discharged EMCs of T-N and T-P were 1.4-2.5 mg/L and 0.059-0.233 mg/L, respectively. Total BOD loading rate through the 3 tributaries to the lake Chinyang was 1,136 kg/d during dry weather. The upper watershed area of the Nam-river dam in this study was divided into 14 catchment basins based on the Korean guideline for total maximum daily load(TMDL) of water quality pollutants. The higher the agricultural land-use ratio, the more NPS loading rate discharged, but the more occupied a forest area, the lower more NPS loading rate discharged. In an agricultural land-use area more than 20%, the increase of NPS loadings might be dramatically diffused by increasing the integrated complex-use like vinyl-house facilities and fertilizer use etc. according to the effective land-use utilization. The NPS loading rates were BOD 0.3 kg/ha-day, SS 0.21 kg/ha-day, TN 0.02 kg/ha-day, TP 0.005 kg/ha-day under less than 10% agricultural land-use. In agricultural land-use of 20%-50%, these values were investigated in the range of 0.32 kg/ha-day-0.73 kg/ha-day for BOD, 0.92 kg/ha-day-3.32 kg/ha-day for SS, 0.70 kg/ha-day-0.90 kg/ha-day TN, 0.03 kg/ha-day-0.044 kg/ha-day for TP.

**Key words** : Non-point source(NPS), Event mean concentration(EMC), Loading, Discharge, Pollution, Runoff

### 1. Introduction

Control of non-point source(NPS) is a recent issue for water quality management of water resources especially in artificial reservoirs such as big multipurpose

dam in Korea. Lake Chinyang is a representative artificial reservoir which is a major water supply source in west side of Geongnam province, south-eastern part of Korean peninsula. Land use of the upstream watershed is mainly for agriculture and

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forest. Lots of researchers reported that eutrophication in lake and dam was caused mainly by non-point source of agricultural and forest areas as well as point source like livestock. The runoff characteristics of NPS pollution load is quite complex in rural area, since the land use is diverse like farming, ranching, and other animal production systems(Loehr, 1974). Organic and inorganic pollutants are discharged even from the forest area. Thus, an understanding of the runoff characteristics of pollutants from a given watershed is necessary for appropriate control measure to assist policy strategies and water resource managements(Gentry et al., 2007). In most agricultural watersheds, phosphorus transport mainly occurred in surface runoff and soil erosion(Kim et al., 2006), while nitrogen transport pathways are considered to be different from those of phosphorus. In this study, NPS contribution was investigated based on flow rates and water qualities of streams into the lake during rainfall event. Event mean concentration (EMC) and the pollution loads were calculated to establish database for NPS control measure in the survey area, and so on, the runoff characteristics of NPS was investigated and estimated based on the ratio of an agricultural to forest area in the stream of sub-catch basin during rainfall event. Non-point source pollution loads were calculated to establish database for NPS control measure in the survey area. And then those data obtained in this study will finally use for water quality improvement of water resources of upstream watersheds of lake Chinyang.

## 2. Materials and Methods

Runoff samples were manually collected at the 3 selected sites which located at the end of three major streams(Gyeongho, Yangcheon and Dukcheon) of the catch basin. Sampling was carried out on short interval time during the first flush rainfall. Flow rate was continuously measured by flow meter at the

sampling site. The upper watershed area of Nam-river dam in this study was divided into 14 catchment basins based on the Korean guideline for TMDL of water quality pollutants. Most of these areas are underlain by agricultural and forested area. These areas were classified into agriculture and forest areas by the land use pattern(see Fig. 2). And the ratio of agriculture area occupied at sub catchment area divided into less than 10%, 20%, 30%, 40% and 50%, then the characteristics of runoff was investigated and estimated from this area. The evaluation for NPS loading rate by runoff for rainfall used the values of flow rate and pollutant concentrations for the streams of the surveyed catch basin area. Flow rate was measured by flow meter at a monitoring site. Stream water sampled at the same site under wet and dry weather. Water quality parameters for analysis were BOD, SS, total nitrogen(TN) and total phosphorus(TP), and were determined by procedures described in the Korean Standard Methods.

The survey was conducted at dawn stream of three major tributaries flowing into the lake Chinyang as shown in Fig. 1. Land use status was summarized for the upstream of the lake in Table 1. The upstream watershed has drainage area of 2,285 km<sup>2</sup> and consists of mainly forest and agricultural purpose area. Average precipitation in the upper watershed is 1400 mmyr<sup>-1</sup>. As shown in Table 2, generation of pollution from land is significant such as 26% of the total BOD load, more than 40% of the SS and TN load. Although TP load is relatively low compared to point sources it is still considerable as a NPS.

The upstream watershed of lake Chinyang which was used to multi- purpose water resource like drinking, industrial and agricultural water has drainage area of 2,285 km<sup>2</sup>, length of waterway 185.6 km, average river width 18.5km and shape factor 0.1 and three main tributaries with 145 branch streams. The Nam river waterway is through two province and reach

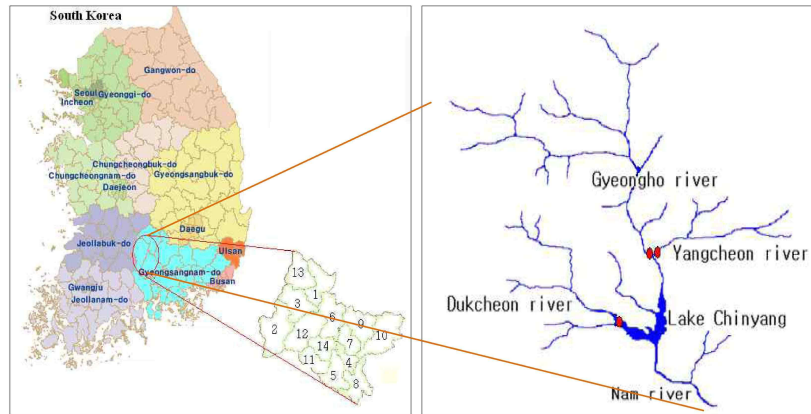


Fig. 1. Map of survey sites (Sub-basin area at the upper watershed of the lake Chinyang).

Table 1. Land use constitution of the upstream watershed of the lake Chinyang

Land use	Total	Dry field	Residence	Forest	Farm	Others
Area(km <sup>2</sup> )	2,285	95.81	30.45	1,728.15	9.72	183.39
Percent(%)	100	4.19	1.33	75.64	0.43	8.02

Table 2. Generation of pollution load from various sources in the survey area

Sources	BOD	Generation daily load(kg/day)		
		SS	T-N	T-P
Domestic	8,199.9	9,190.3	1,122.0	235.9
Livestock	8,577.8	4,558.1	1,345.7	285.8
Land	6,073.7	10,237.3	1,825.3	84.3
Industry	44.7	44.7	26.9	3.6
Total	22,896.1	24,030.4	4,319.9	609.6

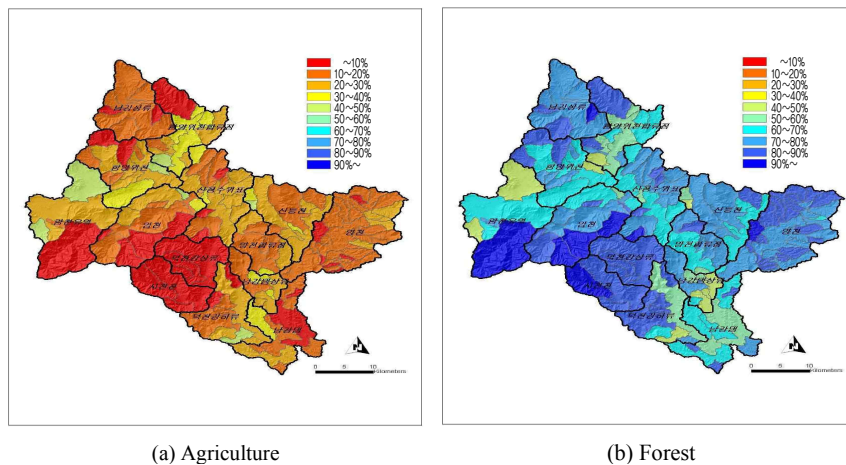


Fig. 2. Ratio of agricultural and forest areas at 14 sub-catchment basin of the upstream watershed in lake Chinyang.

of the Nakdong River. And the upstream watershed is underlain by agricultural and forested area about over 97% and begins at two (Jiri and Dukyu) mountains that are Korea national park. In the climate of this area, there is a strong seasonal cycle with virtually about over 60% of the annual rain precipitation occurring monsoon season (summer) between June and August. Average precipitation in the upper watershed is 1,400 mm/yr.

### 3. Results and Discussion

#### 3.1. Hydro-pollutograph to rainfall event at the survey areas

Fig. 3 shows the precipitation, flow rate, and BOD & TSS in storm surface runoff for a typical rainfall event. Water quality of the three rivers was compared for rainfall and dry period to determine the effect of non-point pollution load by rainfall. As shown in the figure, the hydrograph during rainfall

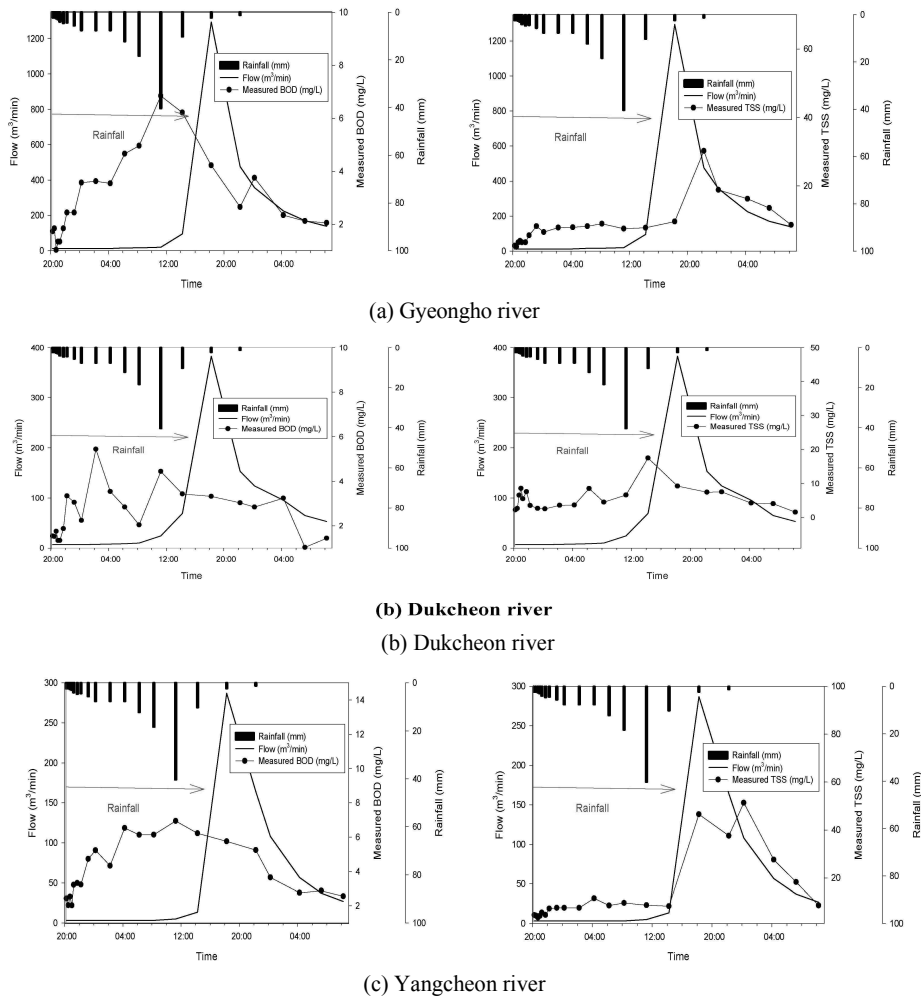


Fig. 3. Precipitation, flow rate and BOD & TSS at the survey sites during rainfall event.

event has a similar shape in all sites, reflecting the rainfall intensity distribution and typical runoff types in agricultural and forest areas. In general, the concentrations of pollutants sharply rise at the early peak time of runoff such as BOD in Fig. 3. However, TSS concentration peaks was observed at the similar time of peak flow. This phenomenon at the watersheds caused by land use and geology types.

3.2. Water quality and loading rates of the three tributaries into the Lake during dry weather

Table 3 shows water quality, flow rates and pollutant loading rate in dry weather in the survey sites. A mean concentration of BOD<sub>5</sub> for three main rivers was in the range of 1.8 mg/L to 3.1 mg/L. A mean flow rate for the 3 rivers was in the range of 41,542~281,219 m<sup>3</sup>/d. BOD loading rate to the lake Chinyang was 787 kg BOD/d, 129 kg BOD/d and 219 kg BOD/d through the 3 rivers, respectively. The ratio on total BOD loading rate to the lake Chinyang was about 70% by Geongho river, and 19% & 11% by Dukcheon river and Yangcheon river, respectively. The contribution rate of three rivers for TN and TP was similar to the trend of BOD.

3.3. EMCs(Event Mean Concentrations) and the loading rates for rainfall event

Generally the overall runoff quality associated with each rainfall event is expressed as event mean concentration (EMC) which is calculated by integrating the product of runoff rate and concentration of substances. The EMC could be used for determining the mass loading to receiving waters. The definition of the EMC is expressed as following equation.

$$EMC = \frac{M}{V} = \frac{\int_0^T q(t)c(t)dt}{\int_0^T q(t)dt}$$

Table 4 shows EMCs and the loading rates for storm surface runoff in the survey sites. The discharged EMC range was 2.9 mg/L~4.8 mg/L in terms of BOD. The discharged EMC of SS ranged 7.7 mg/L~37.7 mg/L. The discharged EMCs of T-N and T-P were 1.4 mg/L~2.5 mg/L and 0.059 mg/L~0.233 mg/L, respectively. The highest pollutant concentration was SS. From the analytical results, reduction of TSS from storm runoff could be a viable control to attenuate pollutant loadings to a receiving water body.

Table 3. Water quality and loading rates of the three tributaries into the Lake Chinyang during dry weather

Watershed name	BOD <sub>5</sub> (mg/L)	T-N (mg/L)	T-P (mg/L)	Average Flow (m <sup>3</sup> /d)	Loading Rate(kg/day)		
					BOD <sub>5</sub>	T-N	T-P
Gyeongho	2.8	1.85	0.034	281,219.04	787.41	520.25	9.56
Yangcheon	3.1	2.28	0.051	41,541.98	128.78	94.72	2.12
Deokcheon	1.8	1.38	0.023	122,133.31	219.84	168.54	2.81
Total	-	-	-	444,894.33	1,136.03	783.51	14.49

Table 4. Variation of EMCs and the pollution load at the survey areas during rainfall

River	Flow rate (10 <sup>6</sup> m <sup>3</sup> /d)	BOD		SS		T-N		T-P	
		loadings (kg/d)	EMCs (mg/L)	loadings (kg/d)	EMCs (mg/L)	loadings (kg/d)	EMCs (mg/L)	loadings (kg/d)	EMCs (mg/L)
Gyeongho	18.9	66,159	3.5	274,089	14.5	37,805	2.0	2,023	0.107
Yangchen	4.8	23,014	4.8	180,759	37.7	8,630	1.8	408	0.085
Deokcheon	6.8	19,702	2.9	52,311	7.7	10,870	1.6	231	0.034

3.4. NPS runoff loadings by the ratio of agricultural land-use at the sub catchment basin

Table 5 shows average runoff pollutant loadings based on agricultural land-used ratio for small stream of sub catch basin area during rainfall event 23.5 mm to 82.1 mm. It clarified to bring similar stream data according to the agricultural land-use ratio. Runoff loadings for BOD from catch basin was not correlated to agricultural land-use, but the

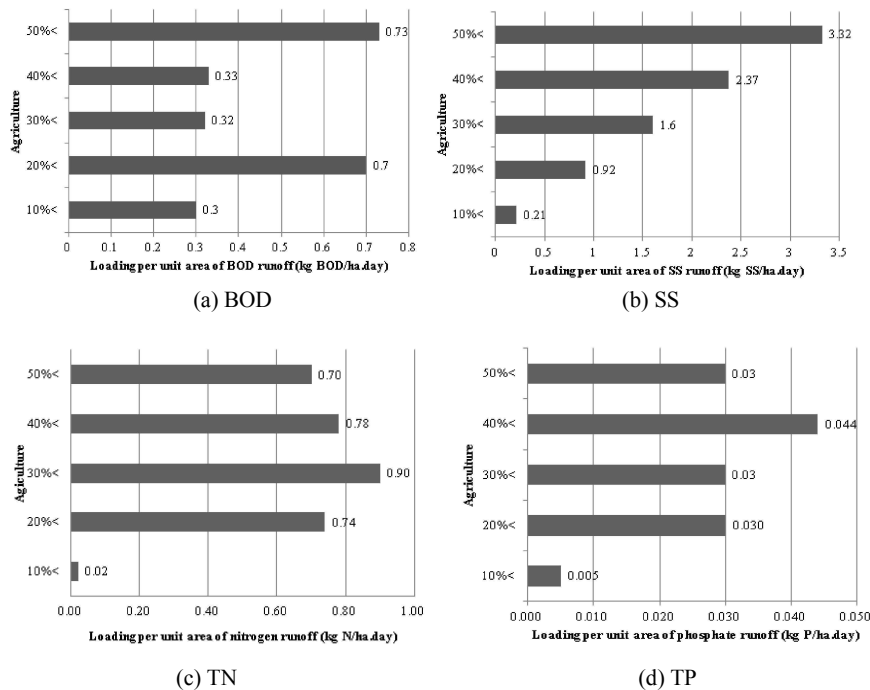
values for nutrients and SS was seem to correlate well according to that ratio.

Fig. 4 shows to summarize average runoff pollutant loadings according agricultural land-use ranking. Runoff loads for TN and TP at other areas except less than 10% an agricultural land-occupy area(that is, forest area) show similar values in the range of 0.7~0.992 kg/ha-d of TN and 0.03~0.0492 kg/ha-d of TP, respectively. These facts might

**Table 5.** Diffuse pollutant loading rates by an agricultural land-use ratio at the sub-catch area

Agricultural land-use(%)	Stream*	Area(km <sup>2</sup> )			Area ratio(%)		BOD <sub>5</sub>	SS	T-N	T-P
		sum	Agri.	Forest	Agri.	Forest				
10%< (1)*	average	100.10	1.91	96.24	1.91	96.15	0.30	0.21	0.02	0.005
20%< (10)	average	45.84	7.01	33.79	16.09	76.97	0.70	0.92	0.74	0.030
30%< (4)	average	15.62	3.95	10.45	23.95	69.05	0.32	1.60	0.90	0.030
40%< (1)	average	19.03	6.47	11.52	33.99	60.55	0.33	2.37	0.78	0.044
50%< (3)	average	30.85	10.75	11.25	42.96	46.78	0.73	3.32	0.70	0.030

\* Number in parenthesis means the number of the surveyed streams in this study



**Fig. 4.** Diffuse pollutant loading rates by an agricultural land-use.

present that many factors affect the miserly different nutrients(TN and TP) runoff loadings from agricultural operation regardless of increasing the agricultural land occupy ratio. Among those are various types of local agricultural land use and community character, the types of crop, crop rotation, soil on which crop is grown, climate change pattern, farming technologies, and irrigation and drainage etc. Another reason is discharged pollutant loadings from waste piles during rain fall events at feedlots and barnyard which is known as the most intensive animal production. The higher the agricultural land-occupy ratio, the more NPS runoff loading rate discharged, but at forest area occupied over 90%, NPS runoff loading rate extremely discharged low. At an agricultural land-use area more than 20%, the NPS runoff loadings might be dramatically more diffuse than 10% by increasing the integrated complex-use like vinyl-house facilities and fertilizer use etc. The results obtained from the survey for agricultural areas, pollutant loads for BOD, SS, T-N, and T-P below those areas 10% were 0.3 kg/ha.d, 0.21 kg/h a.d, 0.02 kg/ha.d, and 0.005 kg/ha.d, respectively. In agricultural land-use of 20%-50%, these values were investigated in range of 0.32~0.73 kg/ha.d for BOD, 0.92~3.32 kg/ha.d for SS, 0.70~0.90 kg/ha.d for TN, 0.03~ 0.044 kg/ha.d for TP.

Table 6 compares average pollutant runoff load from agricultural area investigated in this survey with respect to those data from that of Kyung-an watershed reported by Kim et al.(2002) and of Sumjin river watershed reported by Park et al.(2005). From the results, average pollutants runoff loads of this survey were the values of 58.75 kg/km<sup>2</sup>.day for TN, 2.4 kg/km<sup>2</sup>.day for TP, 1088.94 kg/km<sup>2</sup>.day for SS, and 44.71 kg/km<sup>2</sup>.day for BOD, respectively.

Runoff load for TN of these survey areas was about 18 times lower than that of Kyung-an watershed areas, and then approximately double that of Sumjin

river area. Kyung-an watershed area in which is located nearby Seoul, the capital city of Korea is urban agricultural land-use types, and then Sumjin-river watershed area is mainly occupied rural agricultural land-use, that is almost composed of forest area. It should be noted that the Kyung-an watershed runoff data were representative of urban agricultural watersheds. Runoff loads in that area was strongly affected by the land-development activities around farmland. However TP was not so affected by the land use activity.

**Table 6.** Comparison of runoff NPS pollutant loadings at an agricultural land-use area

Unit : kg/km<sup>2</sup>.day

BOD	SS	T-N	T-P	ref.
44.71	108.94	58.75	2.4	this study
7.6	26.8	1,066.5	4.8	6)
51.02	93.93	25.16	1.05	7)

### 3.5. Pollutant runoff loadings at 14 sub-catchment basins of the upstream watershed of Nam-river Dam

Table 7 shows in order of SS runoff loads according to large amount. As shown in Table 7, there was totally a correlation between that value for SS and the ratio of agricultural land-use to total area, specially into a turbid stream water when it rains. But there is hardly correlation between their values of BOD, TN and TP and the ratio of that. As mentioned above, there are various different types of local agricultural land use and community character, the types of crop, farming technologies, irrigation and drainage, development, and water source conservation zone etc.. Another reason is discharged pollutant loadings from waste piles during rain fall events at feedlots and barnyard which is known as the most intensive animal production. Therefore the contribution degree of diffuse pollutant loadings to water quality of lake Chinyang was strongly affected

**Table 7.** The diffuse pollutant loadings of agricultural area runoff at 14 sub catchment basin in this survey(see Fig. 1)

sub-catch basin	total area (km <sup>2</sup> )	agriculture area(km <sup>2</sup> )	shared ratio(%)	runoff loading rates(kg/km <sup>2</sup> .day)			
				BOD	SS	T-N	T-P
1	161.94	48.00	29.64	35.88	156.13	59.08	2.82
2	263.88	72.09	27.32	41.69	147.15	51.55	2.05
3	178.02	37.24	20.92	38.87	145.05	68.23	2.80
4	71.82	20.86	29.05	50.31	138.76	80.59	3.21
5	143.73	26.37	18.35	48.43	132.36	72.73	2.71
6	195.32	38.38	19.65	44.34	130.98	76.44	2.88
7	100.09	19.64	19.62	57.75	116.72	78.74	3.05
8	162.91	25.98	15.95	46.40	103.84	56.73	2.47
9	85.54	11.14	13.02	55.33	95.06	64.56	2.59
10	179.55	26.45	14.73	65.44	94.01	72.13	2.89
11	268.49	58.53	21.80	41.30	92.21	50.54	2.05
12	218.14	34.68	15.90	47.65	89.65	52.95	2.20
13	160.00	21.33	13.33	22.58	62.29	36.18	1.44
14	106.81	3.59	3.36	30.00	21.00	2.00	0.50
-	2,296.24	409.60	17.84	44.71	108.94	58.75	2.4

by land-use activity character and use types such as intensive livestock, vinyl-house facilities. To be effective in controlling runoff pollutant loads from agriculture, therefore, it is important to understand the local characters and issues for the environments and control options of agricultural production on both public and individual types of land. So the diffuse pollutants were firstly controlled from agriculture land to improve water quality of the upper watershed water body of lake Chinyang.

#### 4. Conclusions

1) At a rainfall event, BOD concentrations rise sharply at the early peak time of runoff, however peaks of TSS concentration was observed at the similar time of peak flow. This was a phenomenon shown at the watersheds caused by forest and geological types. The discharged EMC range was 2.9-4.8 mg/L in terms of BOD. The discharged EMC range was 6.2-8.2 mg/L in terms of SS. The discharged EMCs of T-N and T-P were 1.4-2.5

mg/L and 0.059-0.233 mg/L, respectively.

2) Total BOD loading rate through the 3 tributaries to the lake Chinyang was 1,136 kg/d during dry weather. However it increased to 108,875 kg/d by rainfall which is 95 times greater than that of dry period. Similarly TN and TP load were increased by the NPS to 73 times and 184 times, respectively.

3) The higher the agricultural land-use ratio, the more NPS loading rate discharged, but the more occupied a forest area, the lower more NPS loading rate discharged.

4) At an agricultural land-use area more than 20%, the increase of NPS loadings might be dramatically diffused by increasing the integrated complex-use like vinyl-house facilities and fertilizer use etc. according to the effective land-use utilization. The NPS loading rates were BOD 0.3 kg/ha-day, SS 0.21 kg/ha-day, TN 0.02 kg/ha-day, TP 0.005 kg/ha-day under less than 10% agricultural land-use, respectively. In agricultural land-use of 20%-50%,



these values were investigated in range of 0.32 kg/ha-day-0.73 kg/ha-day for BOD, 0.92 kg/ha-day-3.32 kg/ha-day for SS, 0.70 kg/ha-day-0.90 kg/ha-day TN, 0.03 kg/ha-day-0.044 kg/ha-day for TP.

5) The contribution ratio of diffuse pollutant loadings to Nam-river Dam was strongly affected by land-use activity such as intensive livestock, vinyl-house facilities. So the diffuse pollutants were firstly controlled from agriculture land to improve water quality of the upper watershed water body of lake Chinyang.

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