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Characteristics of Pollutant Loading in Namdae-cheon Watershed

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Abstract

Nonpoint source pollutant loading from watershed may cause a problem to the water quality of the reservoir and stream. The characteristics of stream flow and water quality were monitored to investigate the runoff loading of the Namdae-cheon watershed from May in 1999 to October in 2003. Stage-discharge rating curve at the stream gauging site was established, and annual stream runoff of the study watershed was estimated as 499.4～1,330.8 mm during four years. The concentrations of total-nitrogen and total-phosphorus of stream water quality ranged from 0.76 to 6.95 mg/L and from 0.0010 to 0.2276 mg/L, respectively, where T-N was generally higher than the water quality standard 1.0 mg/L for agricultural water use. The loads by unit generation of pollutant mass with respect to population, livestock, land use in this watershed were calculated. The runoff pollutant loadings by concentrations of total-N and total-P were estimated during study period, where the annual runoff loading of total-P was much less than the load by pollutant mass unit generation. The relations between stream discharge and water quality were analysed, and there was a high correlation for total-N but low for total-P. These results will be used to develop the monitoring techniques and water quality management system of agricultural watershed.

Keywords : Namdae-cheon, pollutant loading, total-nitrogen, total-phosphorus

I. Introduction

Recently the water pollution in stream and lakes has increased because of many factors such as the rapid development and urbanization, industrialization, and increase of quantity and quality of pollutant materials.

Even though much effort was made to improve the ecological environment and water quality by integrated watershed management including water quantity management, it seems to be not made great strides in water quality improvement for suspended materials, heavy metals, dissolved oxygen, nitrogen and phosphorus, agricultural chemicals. Especially agricultural nonpoint source pollutants from watershed flow into stream

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and lakes through rainfall-surface runoff, outflow of excess water with irrigation and drainage from arable lands, which degrades the stream and ground water quality and contribute to the eutrophication. The degradation of stream and lake water quality in Korea was pointed out as one of the most important environmental problems mainly attributed to the increased discharge of various wastewater due to industrialization and urbanization, and improved living standard. That is a reason why the continuous monitoring of hydrologic process and water quality is needed for the proper management of water quality of watershed (Kim, 1998 ; Lee and Lee, 1998 ; Han, 1999).

Many researchers emphasized the necessity on the various efforts and continuous researches to minimize the effects to ecologic environments and development of high technology for the water quality management of watershed. For examples, design of monitoring network for the water quality management (Choi et al., 1996), watershed monitoring and the system design (Chung et al., 1996), effects of land use on the water quality of small agricultural watersheds (Choi et al., 1999), nonpoint source pollution loadings from land uses on small watersheds (Park et al., 1996, 1997), changes of stream water quality and loads of N and P from the agricultural watershed (Jung et al., 1998 ; Chung et al., 1999 ; Choi et al., 2002), and urban runoff and water quality models (Lee, 1998).

This study attempts to provide the basic information for the water quality management of agricultural watershed, and the data of water stage and discharge were monitored in the Namdae-cheon watershed from May in 1999 to October in 2003. Hydrologic characteristics and water qualities were investigated, where water samples were taken and analysed periodically at the gauging point. And runoff loadings were estimated by pollutant mass unit and concentrations of total-nitrogen and total-phosphorus.

Ⅱ. Materials and Methods

1. Study Watershed

The study area is Namdae-cheon watershed as a tributary of Geum river basin, which is located at Seolcheon-myeon and Mupung-myeon, Muju-gun, Jeollabuk-do as shown in Fig. 1. The area of Namdae-cheon watershed is 225.6 km^2 and the length of main stream is 17.8 km with channel slope of 46.9 m/km and shape factor of 0.288. Land use shows that paddy field, upland, forest, and others consist 4.5 %, 7.0%, 86.8 %, and 1.7 % of watershed area, respectively (Cho et al., 2000). The land use of Namdae-cheon watershed is summarized in Table 1. The population of the watershed district was 8,219 persons. For livestock, the number of

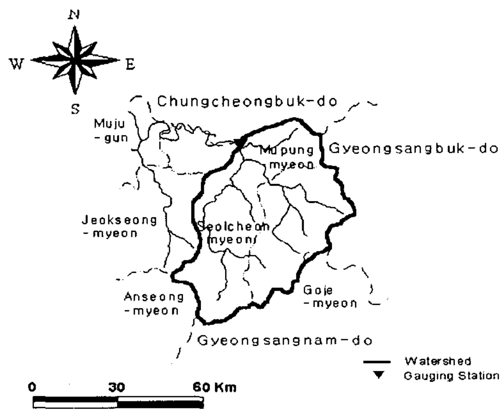


Fig. 1 Map of study area

Table 1 Land use of study watershed

Unit	Total	Land use			
		Paddy	Upland	Forest	Others
ha	22,560	1,011	1,585	19,609	355
(%)	(100)	(4.5)	(7.0)	(86.8)	(1.7)

Korean cattle, daily cattle, pigs and poultry were 804, 118, 1,690 and 1,050 heads in 2002, respectively (Muju-gun, 2002).

2. Hydrologic and Water Quality Monitoring

The rainfall data during the study period were obtained from the Mupung rain gauge station of Mupung-myeon, Muju-gun, Jeollabuk-do. The water levels of the stream at Socheongyo site were monitored using a water level gauge (WL-14, USA and SL-1000, Korea). The amount of water discharge at monitoring site in this tributary was calculated by flow velocities measured using velocity meter (Veleport BMF 002, UK) and the cross-sectional area of the stream.

Water samples were taken at the monitoring site of Namdae-cheon watershed with 1~2 times per month from May 1999 to October 2003, and analysed for the water quality items such as total-N, ammonia-N, nitrate-N and total-P.

Ⅲ. Results and Discussion

1. Precipitation and Stream Discharge

The rainfall data of the Mupung rain gauge station at Mupung-myeon, Muju-gun was employed to the study watershed. Over the 4 years from May 1999 to October 2003, the annual amount of rainfall were 1,119.5 mm in 1999, 1,275.0 mm in 2000, 854.0 mm in 2001, 1,564.0 mm in 2002, 1,663.0 mm (Jan.~Sept.) in 2003, respectively. The annual rainfall in 2002 and 2003 were much more than 1,274 mm of the annual mean precipitation of Korea, but that of 2001 was a extremely small quantity. The maximum monthly rainfall was observed as 805 mm in September 2002, and also the maximum daily rainfall was recorded on September 31 as 327 mm concomitant with typhoon Rusa, which was equivalent to 21 % of the annual rainfall in 2003.

The total amounts of stream flow at monitoring site were observed as 499.4~1330.8 mm during 4 years from 1999 to 2003. The runoff ratios representing the runoff depth to annual rainfall were 58.5~80.0%, which was greater than the

Table 2 Annual rainfall and runoff

Year	Rainfall (mm)	Annual runoff	
		(mm)	(%)
1999	1,119.5	706.6	76.1
2000	1,275.0	946.9	74.3
2001	854.0	499.4	58.5
2002	1,564.0	1,051.4	67.2
2003	1,663.0	1,330.8	80.0

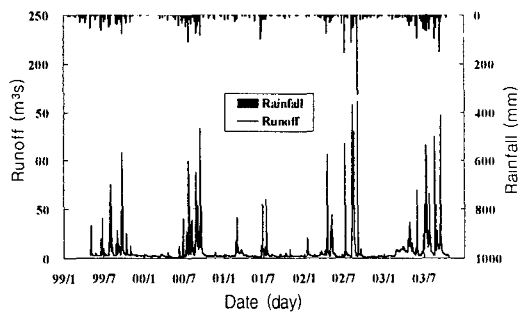


Fig. 2 Daily rainfall and runoff

average value 50 % of Geum river basin. Table 2 and Fig. 2 show the annual and daily rainfall and runoff, respectively.

2. Changes of Water Quality

The changes in the concentrations of nitrogen and phosphorus in stream water at the Soc-heongyo of Namdae-cheon watershed for four years are shown in Fig. 3 and Fig. 4. The concentrations of total-N were 0.76~6.95 (mean 2.45 mg/L), which was mostly higher than the agricultural standard 1.0 mg/L. The nitrogen concentrations were generally increased at the time corresponding to the basal fertilization, tillering fertilization and panicle fertilization to the arable lands. This suggests that agricultural activities might contribute the nutrients to the stream water. Jung et al. (1998) reported that the concentrations of ammonia-N and nitrate-N in stream water of agricultural watershed were 1.24~2.52 mg/L and 6.86~12.04 mg/L, respectively. Chung et al. (1999) also found that the concentrations of ammonia-N and nitrate-N in stream water of agricultural watershed were 0.07~2.37 mg/L and 0.40~17.57 mg/L, respectively. They suggested that variations in total-N and total-P concentrations were influnenced by agricultural activities.

The concentration of total-P was ranged 0.0010~0.0069 mg/L(mean 0.0029 mg/L) in 1999, 0.0010~0.2276 mg/L(mean 0.0342 mg/L) in 2000, 0.0052~0.0086 mg/L(mean 0.0068 mg/L) in 2001, 0.0020~0.0884 mg/L(mean 0.0207 mg/L) in 2002, and the average during study period was from 0.0010 to 0.2276 mg/L (mean 0.0191 mg/L), highest in the period from

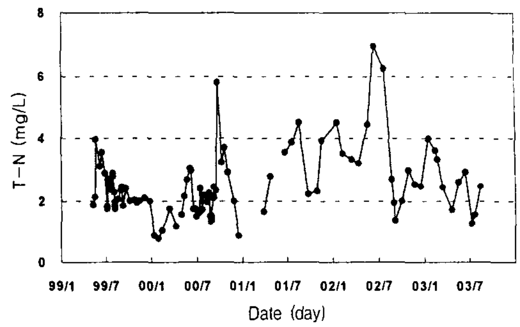


Fig. 3 Changes of total-N

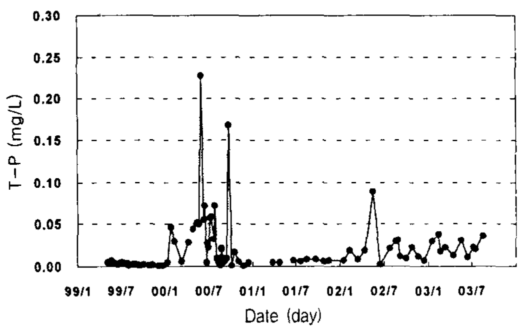


Fig. 4 Changes of total-P

the May to June, when the amount of applied chemical fertilizer to arable lands and runoff from sediments were assumed to be high. Jung et al. (1998) measured changes of phosphorus source concentrations in stream water of agricultural watershed, showing the concentrations of total-P were 0~2.20 mg/L, while soluble-P was hardly detected.

3. Loads of T-N and T-P by unit Generation of Pollutant Mass

The loads of total-N and total-P caused by agricultural activity for study area were calculated by unit generation of pollutant mass. The loads of nitrogen and phosphorus into stream from the arable lands could be different with the type of land use. The loads by agricultural nonpoint sources were estimated with respect to population, livestock and land use for total-N and total-P, respectively.

Loads of nitrogen and phosphorus generated by population were 23,250 kg/yr and 4,890 kg/yr, 65,885 kg/yr and 12,697 kg/yr by livestock, and 269,902 kg/yr and 18,511 kg/yr by land use, respectively. The total loads of nitrogen and phosphorus discharged into stream from watershed were estimated to be 359,037 kg/yr and 36,098 kg/yr, respectively, and summarized in Table 3. For loads of total nitrogen, 75.2 % of total mass generation can be explained by land use, 18.4 % by livestock and 6.5 % by population, respectively. And for loads of total phosphorus, 51.3 % of total mass generation can be explained by land use, 35.2 % by livestock and 13.5 % by population, respectively. This suggests that land use is an impotant factor among nonpoint pollution sources.

Generally, it is extremely difficult to separate the specific share of point source from the nonpoint source pollution from the monitoring results. The most important factors are precipitation and stream flow, and other conditions such as land cover, amount of fertilizers, and sediments, and so on in the particular areas of the watershed. But, the seasonal or annual variations of precipitation, stream flow and agricultural activity are not considered in the generation of pollutant load by mass unit. Therefore, the greatest care must be taken in applying the generation method of polltant mass unit for estimation of runoff loading, and further studies are needed to supplement with consideration of the problems.

Table 3 Pollutant loads by pollutant mass unit

Calss	Pollutant loads (kg/yr)	
	T-N	T-P
Population	23,250	4,890
Livestock	65,885	12,697
land use	269,902	18,511
Total	359,037	36,098

4. Runoff Loading by Water Quality Concentration and Discharge

Assuming that runoff loadings from stream flow mostly occurred by stream flow, loads of nitrogen and phosphorus could be calculated by multiplying water quality concentrations of nitrogen and phosphorus in stream water by the volume of stream flow.

Table 4 show the annual and seasonal runoff loading estimated by water quality concentration. The amount of total-N and total-P were calculated as 258,424~620,890 kg/yr and 960~1,922 kg/yr, respectively. It was shown that the 47.0~79.2 % and 44.8~75.7 % of the annual runoff loadings for total-N and total-P were discharged during irrigation period (May~Sept.). By comparison, there was a difference between runoff loading by concentration and generated load by pollutant mass unit, the reason seems to be not considered the seasonal conditions such as precipitation, stream discharge and agricultural activity which are very important factors explaining nonpoint source of watershed.

Table 4 Runoff loadings of T-N and T-P

(Unit : kg/yr)

Year	Runoff loadings		Irrigation period (May~Sept.)		Non-irrigation period (Oct.~April)	
	T-N	T-P	T-N	T-P	T-N	T-P
1999	305,069	1,141	276,718	864	73,351	277
2000	488,868	1,526	387,222	1,104	101,646	422
2001	258,424	960	121,346	431	137,078	529
2002	509,718	1,539	374,167	1,034	135,551	504
2003	620,890	1,922	448,382	1,321	172,508	601
Mean	445,594	1,417	321,567	951	124,027	467

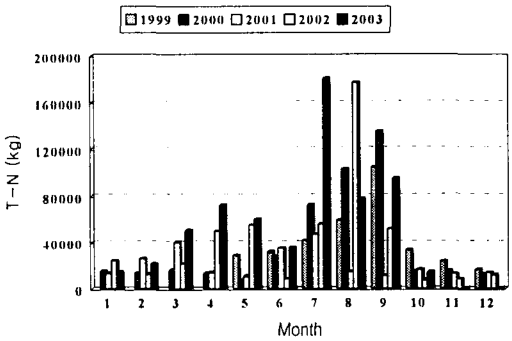


Fig. 5 Runoff pollutant loadings of T-N

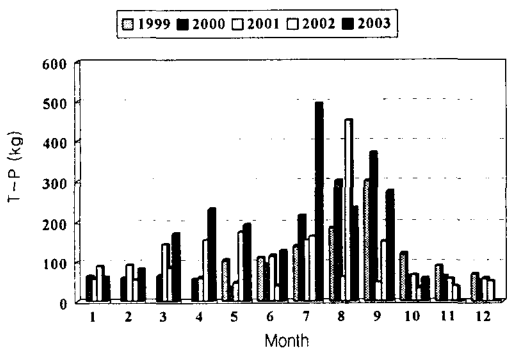
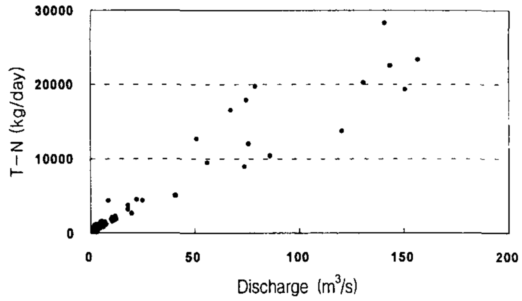


Fig. 6 Runoff pollutant loadings of T-P

5. Relations between Runoff Loading and Discharge

The relationship between runoff loading and discharge obtained from using the water quality concentrations and stream discharge at Namdae-cheon was shown in Fig. 7. Using these relationships with daily discharge, the daily runoff loading could be calculated. From the analysis, the regression equations $Y = 221.18 X^{0.9291}$ for total-N and $Y = 1.04 X^{0.7840}$ for total-P were induced with determination coefficients of 0.9214



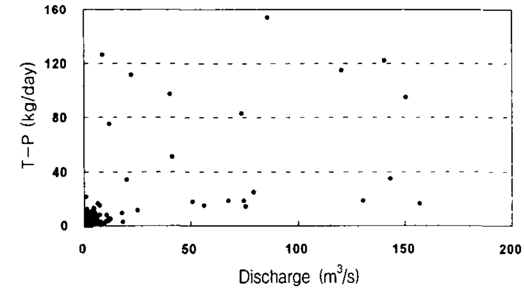


Fig. 7 Relationship between discharge and pollutant loads of T-N and T-P

and 0.4480, respectively. Here, Y is daily runoff loading of total-N and total-P, and X is discharge. It showed that there was a close relation for total-N, but low for total-P relation.

On the other hand, the annual runoff loadings for total-N obtained from the relationships between runoff loadings and discharge were 367,488 kg/yr in 1999, 443,749 kg/yr in 2000, 287,416 kg/yr in 2001, 579,243 kg/yr in 2002, and 674,422 kg/yr in 2003, respectively. And the annual runoff loadings for total-P obtained from the relationships between runoff loadings and discharge were 412 kg/yr in 1999, 580 kg/yr in 2000, 699 kg/yr in 2001, 2,368 kg/yr in 2002, and 3,906 kg/yr in 2003, respectively. The average runoff loadings for total-N were 470,464 kg/yr and 1,593 kg/yr for total-P, respectively.

Ⅳ. Conclusion

Hydrologic and water quality monitoring was carried out in the Namdae-cheon watershed with 22,560 ha during over four years from May 1999 to October 2003. The annual rainfall were observed as 854~1,663.0 mm, especially those in 2002 and 2003 were much more than annual mean precipitation 1,274 mm of Korea The total amounts of stream flow were 499.4~1,330.8 mm and runoff ratio were 58.5~80.0 % per year, and which was a little higher than the average in Geum river basin.

The concentrations of total-N were 0.76~6.95 mg/L (mean 2.45 mg/L), which was generally higher than the agricultural standard 1.0 mg/L, and those of total-P from 0.0010 to 0.2276 mg/L (mean 0.0191 mg/L). The total loads of nitrogen and phosphorus by agricultural nonpoint sources were estimated with respect to population, livestock and land use, which were 359,037 kg/yr for total-N and 36,098 kg/yr for total-P, respectively.

Based on annual amount of stream flow of the study watershed, the amount of runoff loadings of total-nitrogen and total-phosphorus by water quality concentrations were estimated as 258,424~620,890 kg/yr and 960~1,922 kg/yr, respectively. The 47.0~79.2 % and 44.8~75.7 % of the annual runoff loadings were estimated to be discharged during irrigation period. And, there was a great difference each year between runoff loading by concentration and generated load by pollutant mass unit, it seems to be not considered the seasonal conditions such as precipitation, stream discharge and agricultural activity. The relations between stream flow and runoff loading by water quality concentration showed a high correlation for only total-N. These results can be used to understand the variation of stream flow and water quality, and applied to design the watershed management system for water quality conservation of agricultural watershed.

Acknowledgements

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